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Special Issue Reprint

Human Geography

Interrelationships between People, Place, and the Environment

Edited by
Giuseppe T. Cirella

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Human Geography: Interrelationships between People, Place, and the Environment

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Guest Editor

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About the Editor

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Editorial

Human Geographies in Action: Insights into Migration, Development, Culture, and Sustainability

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1. Introduction

Human geography today goes beyond traditional mapping, integrating environmental, social, and economic factors to tackle real-world issues. One critical aspect is the way urban spaces can be designed to balance ecological health with human development. Urban green infrastructure is a key solution, with research showing how these spaces contribute to air pollution removal while adding significant economic value through ecosystem services [1,2]. Green infrastructure thus offers a dual benefit, improving public health and supporting long-term sustainability goals. Another layer of complexity in urban sustainability is addressing vulnerabilities due to climate-related hazards [3]. Coastal urban areas are particularly at risk, and cities must incorporate resilience strategies that address these unique vulnerabilities [4]. Climate risk assessments for such regions show that effective planning can reduce the impacts of flooding and extreme weather, underscoring the importance of proactive approaches to urban development in the face of climate change.

Financial services, as part of urban infrastructure, also play a critical role in sustainable development. The spatial arrangement of financial institutions affects economic growth and equitable access to resources, a dynamic that is crucial for urban economic health [5]. The clustering of financial services has implications for wealth distribution within cities, shaping the broader patterns of urban development and supporting or challenging sustainable growth. Additionally, robust smart network implementation and security enforcement ensure that financial enterprises operate efficiently and securely, further enhancing their role in urban infrastructure and economic resilience [6]. In addition to these infrastructural components, public willingness to support environmental initiatives has become essential to sustainable urban management. Studies on people's willingness to pay for ecosystem services show that community support is fundamental for long-term environmental stewardship [7]. When residents are willing to financially contribute to watershed management or green spaces, it demonstrates a shared commitment to sustainability, further encouraging participatory approaches to urban planning.

Understanding how resources flow within cities also supports sustainability. Research on tourism revenue in the Yangtze River Delta, for instance, illustrates how economic activities can be aligned with environmental goals [8]. Tourism, when managed with sustainability in mind, can be a source of revenue without compromising urban green spaces and local resources. Spatiotemporal analyses like this provide urban planners with insights on maximizing economic gains while safeguarding environmental assets. The practical applications of sustainability frameworks can also be seen through the index of sustainable functionality (ISF). This tool evaluates the sustainability of urban areas by analyzing their ecological, social, and economic health, offering planners a roadmap for improvements [9,10]. In regions such as Urat Front Banner in Inner Mongolia Autonomous Region, China, where the ISF was applied, this approach effectively highlighted areas for improvement, showcasing how cities can leverage data-driven assessments to more strategically advance sustainability goals.

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On a broader scale, fiscal management plays a crucial role in shaping sustainability outcomes, particularly in post-communist European Union (EU) countries where balancing debt, deficits, and urban development presents an ongoing challenge. Cities in these transition economies face tough decisions as they juggle immediate financial stability with the need for sustainable growth [11]. Financial strategies in these areas must therefore be adaptive, addressing short-term budget constraints while keeping an eye on long-term environmental goals. Parallel to these economic strategies, regional and local approaches to sustainability, like water management, offer models of how sustainability can be deeply integrated into urban growth. In Northern China, for instance, merging water management with wetland restoration not only preserves crucial ecosystems but also supports urban expansion, creating a mutually beneficial solution [12]. These combined strategies underscore the adaptability of human geography, where solutions are uniquely tailored to harmonize both environmental preservation and urban development.

Achieving these sustainability objectives requires both effective strategies and efficient implementation, as highlighted in performance management systems. Cities need systems that balance the long-term vision of sustainability with the practical demands of everyday governance [13]. These systems help ensure that sustainability initiatives are both feasible and impactful, creating a strong foundation for lasting change. Together, these insights reveal how human geography provides the analytical and strategic tools needed to shape sustainable cities. By understanding the interconnections between ecological health, social equity, and economic stability, human geographies offer a comprehensive approach to the challenges cities face today. Research in environmental management, climate resilience, economic systems, and community engagement highlights the vital role human geography plays in crafting cities that are both thriving and sustainable. By integrating these areas, human geography moves from theory to tangible action, creating a foundation upon which urban areas can grow resiliently, equitably, and sustainably in an increasingly complex world.

2. Synopsis of Contributions

This Special Issue (SI), titled "Human Geography: Interrelationships between People, Place, and the Environment," represents a significant advancement in human geography scholarship. Comprising 25 contributions, it offers a thorough and nuanced examination of the field, blending both foundational ideas and emerging perspectives. Each article provides fresh insights that deepen our understanding of human geography, with a particular focus on the key concepts of people, place, and the environment, as well as the dynamic and interconnected relationships between them. Through these diverse explorations, the SI encourages readers to engage with innovative ways of thinking about spatial and temporal connections, highlighting how human experiences are shaped by complex and interdependent environments. The SI is organized into five thematic sections: migration and population studies, urban and rural development, cultural and social geography, political and economic geography, and environmental and sustainability studies. Figure 1 illustrates the global distribution of research and authorship, emphasizing the broad geographic reach and collaborative nature of this work. Collectively, these contributions underscore the international scope of the field and the increasing value of cross-cultural insights, reinforcing the importance of diverse perspectives and methodologies in tackling the spatial and social complexities of contemporary human geography.

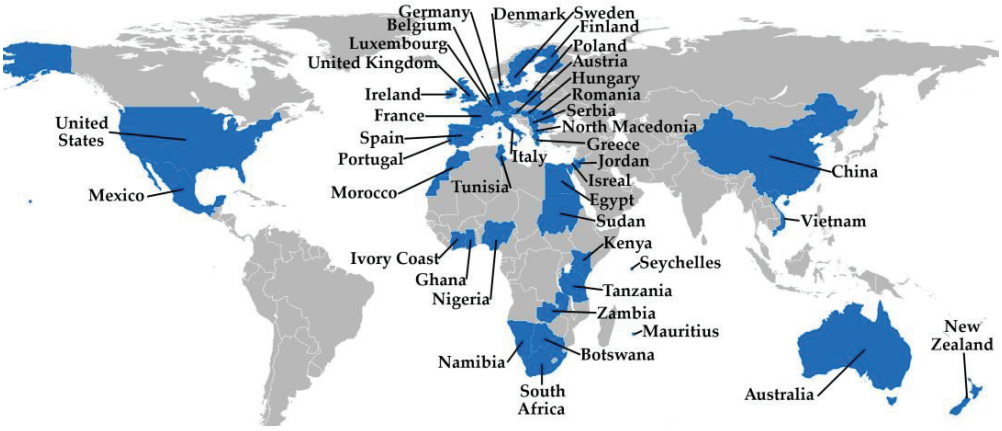


Figure 1. Global distribution of research contributions and authorship locations in this SI.

2.1. Migration and Population Studies

Migration and population dynamics are central themes in human geography, where the movement of people is influenced by various environmental, social, and economic factors. Understanding these movements is critical to addressing both local and global challenges, as seen through several studies from different parts of the world. The article by Adekola et al. (Contribution 1) examines the economic drivers behind the voluntary return of internally displaced persons (IDPs) in North-East Nigeria, which has been recovering from a decade of violent conflict. Millions of people were displaced by Boko Haram insurgencies, and the study reveals that the willingness of these displaced persons to return home is strongly influenced by the availability of jobs upon return. This research emphasizes the economic incentives that are necessary for the reintegration process, suggesting that providing employment opportunities would significantly encourage the displaced population to return and rebuild their communities.

In contrast, Cao et al. (Contribution 2) explore a different dimension of migration within urban contexts, focusing on intra-urban residential relocation in Nanjing, China. Their study highlights the mental and physical health impacts of residential mobility on the elderly, particularly when relocation involves long distances or frequent moves. The findings suggest that relocation away from the urban core to surrounding areas may improve mental health but can negatively affect physical health, particularly when the elderly experience frequent relocations. This research underscores the complexity of migration within cities and its varying effects on different demographic groups.

A broader perspective on population migration within urban agglomerations is offered by Cao et al. (Contribution 3), who analyze migration patterns in Chinese urban areas. The study identifies various agglomeration patterns—monocentric and polycentric—and highlights how economic development and social conditions shape migration flows. This research connects population mobility with the spatial dynamics of urban growth, offering important insights into the planning of urban spaces to better accommodate these flows and foster sustainable development.

Langović et al. (Contribution 4) provide further insights into return migration, focusing on Serbia. Their study examines the factors influencing return migration, showing that emotional ties to the homeland and satisfaction with life post-return vary significantly across different returnee groups. The sustainability of return migration, the study concludes, is closely linked to life satisfaction, suggesting that policies aimed at improving quality of life and economic conditions for returnees can promote more sustainable reintegration.

Lastly, Le et al. (Contribution 5) employ geographic information system (GIS) technology to examine the spatial relationships between migration flows, housing prices, and

demographics in Greater Manchester, UK. Their analysis reveals clear patterns linking migration to housing markets, with specific age groups and housing price levels affecting where people migrate. This study highlights the potential of spatial data analysis to inform migration policy and urban planning decisions. Together, these studies illustrate the multifaceted nature of migration and population studies, showing that economic, social, and spatial factors play pivotal roles in shaping migration patterns and their outcomes. Each piece contributes to a deeper understanding of the dynamics that govern how populations move and settle, both within and across borders.

2.2. Urban and Rural Development

Urban and rural development is a dynamic process, shaped by socioeconomic and environmental factors that often blur the lines between urban and rural areas. The relationships between small towns and rural communities play a significant role in shaping the living standards of rural populations. A study by Bogdański and Janusz (Contribution 6) explores how small towns in the Warmińsko-Mazurskie region of Poland contribute to the standard of living in surrounding rural areas. The research shows that as small towns perform more functions, such as offering services and infrastructure, the quality of life in rural areas improves. However, despite these positive effects, disparities between rural and urban regions remain persistent, highlighting the challenges of reducing socioeconomic inequalities.

In urban areas, resilience to socioeconomic and environmental challenges is key to long-term development. Liu et al. (Contribution 7) focus on Beijing's central area, assessing the socio-spatial resilience of the city during its transitional period from 1990 to 2020. Their study reveals that while overall resilience increased, social divisions within the city hindered the development of social capital, particularly in highly diverse areas. This underscores the importance of strengthening community ties and building inclusive urban spaces to better handle future uncertainties.

Meanwhile, urban shrinkage, a phenomenon that affects both urban and rural spaces, has become an increasing concern in China. Ding et al. (Contribution 8) examine urban shrinkage in the Yellow River Basin, noting that cities in peripheral areas are shrinking due to factors such as economic transition and aging populations. This regional shift presents challenges for urban planning and policy, demanding attention to how peripheral areas are integrated into broader urban and rural development strategies.

Finally, environmental factors such as land loss also impact rural and urban resilience. Hinz et al. (Contribution 9) explore the social implications of coastal land loss in Louisiana, highlighting how affected communities perceive and react to environmental degradation. Their study suggests that resilience is not just about physical infrastructure but also about how communities interpret and adapt to environmental changes, revealing the complex interaction between natural landscapes and human settlements. These studies highlight the intricate dynamics of urban and rural development, underscoring the importance of policies that can effectively address the challenges and harness the opportunities within these interconnected spaces.

2.3. Cultural and Social Geography

Cultural and social geography explores how territorial branding, social norms, and cultural identities influence human-environment interactions. A key aspect of this is how territorial branding impacts both the physical and cultural landscapes of cities and regions. Almeida (Contribution 10) investigates power relations in territorial brands, revealing the complex connections between branding and regional power dynamics. The study develops an analytical matrix that uncovers how territorial brands function as legitimizing mechanisms, emphasizing their role in shaping both local and global discourses and, ultimately, the identity of urban spaces.

Moving from conceptual branding to more tangible forms of heritage, Cattaneo et al.'s (Contribution 11) research investigates the territorial effects of shared-living heritage regeneration. This study focuses on the adaptive reuse of ancient community buildings, such as

the Tulou in China and the Marae in New Zealand. The authors show that regeneration projects, while fostering sustainable development, also revitalize cultural heritage and build social cohesion among diverse community groups. Through expert interviews, they demonstrate how these projects create a mix of income groups, fostering inclusivity and resilience in rural contexts.

Further enriching this theme, Liu et al.'s (Contribution 12) work examines village development types using a natural socioeconomic framework, contributing to the understanding of rural revitalization. By categorizing villages based on natural suitability and socioeconomic factors, Liu et al.'s study provides a framework for rural planning, helping policymakers identify sustainable pathways for development while preserving cultural heritage.

Finally, Vörös et al. (Contribution 13) explore how cultural stereotypes influence social behaviors, specifically in the realm of car navigation. Their study of navigation habits across Hungary, Romania, and Austria reveals that social factors like age, gender, and financial situation impact driving behaviors, suggesting that cultural assumptions play a role in shaping everyday experiences. This research contributes to a deeper understanding of how stereotypes influence spatial and social practices in urban and rural contexts. The interconnections between culture, power, and spatial dynamics highlight how human geography, viewed through cultural and social lenses, plays a pivotal role in shaping the territories we inhabit.

2.4. Political and Economic Geography

In the realm of political and economic geography, the interaction between economic structures and political landscapes is critical for understanding sustainability and growth. This section delves into the economic forces driving labor market flexibility, stock exchange maturity, and human activity's environmental impact, offering insights into how economic policies can shape the broader social and political fabric. Starting with Próchniak et al. (Contribution 14), the analysis of African stock exchanges sets the stage by exploring how financial markets in Africa contribute to sustainability. The research uncovers the varying maturity levels of stock exchanges, with more developed exchanges such as the Johannesburg, Nigerian, and Egyptian exchanges emerging as leaders in supporting sustainable practices. This assessment highlights the importance of financial frameworks in shaping the continent's economic future and sustainability goals.

Next, Galik et al. (Contribution 15) shift focus to labor market flexibility, using the TOPSIS method to evaluate the adaptability of labor markets across EU member states. The findings underscore how sustainable industrial relations and social policies can enhance labor market flexibility, a critical element in fostering long-term economic growth and stability, especially in the face of challenges like the COVID-19 pandemic. Finally, Aggestam (Contribution 16) broadens the lens by examining the political implications of economic and environmental policies in the EU. The study contrasts the EU's Nature Restoration Regulation with the Kunming-Montreal Global Biodiversity Framework, emphasizing the need for more integrated and effective forest management strategies. The research shows how political decisions in environmental governance impact economic sustainability, particularly in sectors like forestry.

In all, these studies illustrate the interconnectedness of economic strategies, labor market policies, and environmental governance in shaping sustainable and resilient political economies. This highlights the role of economic frameworks in fostering both political stability and environmental sustainability, offering valuable insights into the dynamics of global sustainability.

2.5. Environmental and Sustainability Studies

The intersection of environmental and sustainability studies with human geography reflects a vital effort to balance human needs with environmental preservation, especially in vulnerable and evolving regions. As the world faces increasing ecological and socioeconomic challenges, the role of sustainable practices in agriculture, land restoration, and population

health becomes even more critical. In China's ethnic minority areas, Huo et al. (Contribution 17) explore how population growth, under the country's relaxed family planning policies, impacts sustainable development. Their study in the Hotan region highlights the strain on resources and the environment, underscoring the need for integrated economic and demographic planning to foster long-term sustainability. Similarly, Ma et al. (Contribution 18) examine the relationship between women's well-being and ecological factors in Northwest China. By assessing the Women's Development Index across ecologically vulnerable areas, they reveal how environmental conditions affect both physical and mental health, demonstrating the essential link between ecological balance and human well-being.

Further west, in Israel, Luz (Contribution 19) sheds light on the complexities of sustainable agriculture. This study of Israeli farmers illustrates how local practices are vulnerable to global agricultural policies and climate change. Luz argues that a broader, multiscalar approach—spanning local to global levels—is necessary to drive meaningful changes in farming practices that prioritize sustainability. In Jordan, Qutieshat and Al-Assaf (Contribution 20) take a different approach by investigating the impact of urbanization and altitude variability on disaster risk management. Their research connects the loss of green spaces and the expansion of built environments to increased landslide risks, emphasizing how urbanization can exacerbate natural hazards, further straining already vulnerable regions.

Finally, Tang et al. (Contribution 21) examine the coupling of population health and economic development in China, revealing how the two are intertwined with ecological sustainability. Their study highlights the need for coordinated efforts to improve public health while fostering economic growth, with an awareness of the spatial and temporal dynamics of these issues. Together, these studies reflect the growing need for interdisciplinary approaches to sustainability—integrating population dynamics, agricultural practices, urbanization, and health to create resilient, balanced solutions for both people and the planet.

3. Conclusions

At the core of this SI lies the concept of interrelationships—the intricate connections between people, place, and the environment, each influencing the other and shaping their development over time. These interconnections form the foundation of the contributions in this SI, with each article offering a unique perspective on how human geography deepens our understanding of these complex dynamics. The importance of interrelationships is especially evident in discussions on sustainability, a theme woven throughout this SI. Sustainability demands a comprehensive approach that recognizes the interconnectedness of human and physical systems and strives to find equilibrium between progress and preservation. The contributions in this SI explore critical sustainability issues, ranging from urban resilience and climate adaptation to justice and resource management.

To fully grasp and analyze the complexities of these interrelationships, a diverse range of research methods is essential. This SI highlights the value of methodological pluralism, incorporating both quantitative and qualitative approaches, alongside advanced techniques in spatial analysis, spatial statistics, and GIS. Together, these methods form a robust toolkit that enables human geographers to map spatial patterns, analyze data, and model the interactions between people and their environments.

A central goal of this SI is to bridge the gap between theory and practice. Human geography offers powerful frameworks for addressing real-world challenges, from urban planning and economic development to conservation and equity. The articles featured in this SI showcase how human geography can tackle pressing issues such as climate change, resource scarcity, and inequality, contributing to knowledge that is not only academically rigorous but also socially relevant. This SI invites readers to reflect on how human geography can inform policies and practices that support sustainable development, responsible stewardship, and social justice. By situating human geography within the broader context of sustainability, this SI underscores the need to balance human demands with environmental limitations—an essential consideration across the various subdisciplines explored throughout this SI.

In conclusion, "Human Geography: Interrelationships between People, Place, and the Environment" serves as a testament to the dynamism and relevance of human geography today. Through its 25 contributions, this SI not only advances our understanding of key themes but also highlights the importance of collaboration, innovation, and practical application. By exploring the economic, cultural, social, political, and historical intersections within human geography, this SI offers a comprehensive framework for analyzing the diverse ways people and their environments shape one another.

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List of Contributions

1. Adekola, P.O.; Azuh, D.E.; Amoo, E.O.; Brownell, G.; Cirella, G.T. Economic Drivers of Voluntary Return among Conflict-Induced Internally Displaced Persons in Nigeria. *Sustainability* **2022**, *14*, 2060. https://doi.org/10.3390/su14042060.
2. Cao, Y.; He, X.; Zhou, C. Characteristics and Influencing Factors of Population Migration under Different Population Agglomeration Patterns—A Case Study of Urban Agglomeration in China. *Sustainability* **2023**, *15*, 6909. https://doi.org/10.3390/su15086909.
3. Cao, Y.; Wang, Y.; Wu, H.; Zhang, C.; Shen, S.; Qu, Y.; Yan, S. Does Intra-Urban Residential Relocation Affect the Elderly's Health and Well-Being? An Empirical Study of Nanjing, China. *Sustainability* **2023**, *15*, 12125. https://doi.org/10.3390/su151612125.
4. Langović, M.; Djurkin, D.; Krstić, F.; Petrović, M.; Ljakoska, M.; Kovjanić, A.; Vukašinović, S. Return Migration and Reintegration in Serbia: Are All Returnees the Same? *Sustainability* **2024**, *16*, 5118. https://doi.org/10.3390/su16125118.
5. Le, T.Q.; Doan, L.-V.-L.; Le, H.N. An Approach to Analyzing Migration Flow and House Price Data: Exploring Spatial Linkages between Flow, Price, Distance, Age at the Local Level. *Sustainability* **2024**, *16*, 7087. https://doi.org/10.3390/su16167087.
6. Bogdański, M.; Janusz, M. Small Towns' Functions as a Determinant of the Standard of Living in Rural Areas—An Example from Poland. *Sustainability* **2022**, *14*, 13254. https://doi.org/10.3390/su142013254.
7. Liu, Y.; Bu, S.; Zhang, S.; Xu, C. Research on the Socio-Spatial Resilience Evaluation and Evolution of the Central Area of Beijing in Transitional China. *Sustainability* **2024**, *16*, 7098. https://doi.org/10.3390/su16167098.
8. Ding, X.; Yu, S.; Miao, Y.; Wang, C.; Jin, Z. Types, Modes and Influencing Factors of Urban Shrinkage: Evidence from the Yellow River Basin, China. *Sustainability* **2022**, *14*, 9213. https://doi.org/10.3390/su14159213.
9. Hinz, L.; Weber, A.-M.; Koegst, L.; Kühne, O. A Neopragmatic Perspective on the Processual Nature of Landscape—Coastal Land Loss in Louisiana in the Context of Scientific Findings, Social Patterns of Interpretation, and Individual Experience. *Sustainability* **2024**, *16*, 2078. https://doi.org/10.3390/su16052078.
10. Almeida, G.G.F. Unraveling Power Relations: An Analytical Matrix for Territorial Brands. *Sustainability* **2024**, *16*, 2795. https://doi.org/10.3390/su16072795.
11. Cattaneo, T.; Giorgi, E.; Flores, M.; Barquero, V. Territorial Effects of Shared-Living Heritage Regeneration. *Sustainability* **2020**, *12*, 8616. https://doi.org/10.3390/su12208616.

12. Liu, Y.; Liu, J.; Guo, C.; Zhang, T.; Wang, A.; Yu, X. Identification of Villages' Development Types Using a Comprehensive Natural–Socioeconomic Framework. *Sustainability* **2021**, *13*, 7294. https://doi.org/10.3390/su13137294.
13. Vörös, F.; Gartner, G.; Peterson, M.P.; Kovács, B. Do Social Aspects Affect Built-in Car Navigation Habits? A Stereotype Study. *Sustainability* **2023**, *15*, 5203. https://doi.org/10.3390/su15065203.
14. Próchniak, J.; Płoska, R.; Zamojska, A.; Lepczyński, B.; Cirella, G.T. Maturity Analysis of Stock Exchanges in Africa: Prepandemic Sustainability Perspective. *Sustainability* **2023**, *15*, 6820. https://doi.org/10.3390/su15086820.
15. Galik, A.; Bąk, M.; Bałandynowicz-Panfil, K.; Cirella, G.T. Evaluating Labour Market Flexibility Using the TOPSIS Method: Sustainable Industrial Relations. *Sustainability* **2022**, *14*, 526. https://doi.org/10.3390/su14010526.
16. Aggestam, F. Crosswalking the EU Nature Restoration Regulation and the Kunming-Montreal Global Biodiversity Framework: A Forest-Centred Outlook. *Sustainability* **2024**, *16*, 4863. https://doi.org/10.3390/su16114863.
17. Huo, J.; Zhang, X.; Zhang, Z.; Chen, Y. Research on Population Development in Ethnic Minority Areas in the Context of China's Population Strategy Adjustment. *Sustainability* **2020**, *12*, 8021. https://doi.org/10.3390/su12198021.
18. Ma, J.; Lei, M.; Yu, H.; Li, R. A Study on Temporal and Spatial Differences in Women's Well-Being in an Ecologically Vulnerable Area in Northwest China. *Sustainability* **2023**, *15*, 2324. https://doi.org/10.3390/su15032324.
19. Luz, N. The Treacherous Road to Sustainable Agriculture: Lessons from Israeli Farmers and the Need to Upscale the Debate. *Sustainability* **2023**, *15*, 12388. https://doi.org/10.3390/su151612388.
20. Qutieshat, R.; Al-Assaf, T. The Relationships between Urbanization, Altitude Variability and Disaster Risk Management, Evidence from Jordan. *Sustainability* **2022**, *14*, 9241. https://doi.org/10.3390/su14159241.
21. Tang, H.; Chen, Y.; Ao, R.; Shen, X.; Shi, G. Spatial–Temporal Characteristics and Driving Factors of the Coupling Coordination between Population Health and Economic Development in China. *Sustainability* **2022**, *14*, 10513. https://doi.org/10.3390/su141710513.

References

1. Russo, A.; Chan, W.T.; Cirella, G.T. Estimating Air Pollution Removal and Monetary Value for Urban Green Infrastructure Strategies Using Web-Based Applications. *Land* **2021**, *10*, 788. [CrossRef]
2. Russo, A.; Cirella, G.T. Urban Ecosystem Services: Current Knowledge, Gaps, and Future Research. *Land* **2021**, *10*, 811. [CrossRef]
3. Cirella, G.T.; Semenzin, E.; Critto, A.; Marcomini, A. Natural Hazard Risk Assessment and Management Methodologies Review: Europe. In *Sustainable Cities and Military Installations*; Linkov, I., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 329–358.
4. Cirella, G.T.; Iyalomhe, F.; Russo, A. Vulnerability and Risks Related to Climatic Events in Urban Coastal Environments: Overview of Actuality and Challenges of Methodologies and Approaches. *UPLanD–J. UrbanPlan. Landsc. Environ. Des.* **2016**, *1*, 67–76. [CrossRef]
5. Fu, Y.; Yang, X.; Wang, T.; Supriyadi, A.; Cirella, G.T. Spatial Pattern Characteristics of the Financial Service Industry: Evidence from Nanjing, China. *Appl. Spat. Anal. Policy* **2022**, *15*, 595–620. [CrossRef]
6. Makeri, Y.A.; Cirella, G.T.; Galas, F.J.; Jadah, H.M.; Adeniran, A.O. Network Performance Through Virtual Local Area Network (VLAN) Implementation & Enforcement on Network Security for Enterprise. *Int. J. Adv. Netw. Appl.* **2021**, *12*, 4750–4762. [CrossRef]
7. Abebe, S.T.; Dagnew, A.B.; Zeleke, V.G.; Eshetu, G.Z.; Cirella, G.T. Willingness to Pay for Watershed Management. *Resources* **2019**, *8*, 77. [CrossRef]
8. Jiao, G.; Lu, L.; Chen, G.; Huang, Z.; Cirella, G.T.; Yang, X. Spatiotemporal Characteristics and Influencing Factors of Tourism Revenue in the Yangtze River Delta Urban Agglomeration Region during 2001–2019. *Sustainability* **2021**, *13*, 3658. [CrossRef]
9. Cirella, G.T.; Zerbe, S. Index of Sustainable Functionality: Application in Urat Front Banner. In *Sustainable Water Management and Wetland Restoration in Settlements of Continental-Arid Central Asia*; Cirella, G.T., Zerbe, S., Eds.; Bozen University Press: Bozen, Itaty, 2014; pp. 137–155, ISBN 978-88-6046-069-1.
10. Cirella, G.T.; Zerbe, S. Index of Sustainable Functionality: Procedural Developments and Application in Urat Front Banner, Inner Mongolia Autonomous Region. *Int. J. Environ. Sustain.* **2015**, *10*, 15–31. [CrossRef]

11. Paczoski, A.; Abebe, S.T.; Cirella, G.T. Debt and Deficit Growth Rate Reporting for Post-Communist European Union Member States. *Soc. Sci.* **2019**, *8*, 173. [CrossRef]
12. Cirella, G.T.; Zerbe, S. *Sustainable Water Management and Wetland Restoration in Settlements of Continental-Arid Central Asia*; Free University of Bozen: Bozen, Itaty, 2014; ISBN 978-88-6046-069-1.
13. Lewandowski, R.A.; Cirella, G.T. Performance Management Systems: Trade-off between Implementation and Strategy Development. *Oper. Manag. Res.* **2023**, *16*, 280–295. [CrossRef]

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Article

The Primacy Evaluation and Pattern Evolution Mechanism of the Central City in Nanjing Metropolitan Area

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Abstract: Economic globalisation has accelerated the cross-regional flow of resource elements and broken through the constraints of traditional regional administrative boundaries. Urban agglomerations are core carriers that drive and accelerate regional integration development and can promote the division of urban functions and cooperation. This study considers the Nanjing metropolitan area as a case study to construct a comprehensive first-degree evaluation index system for cities from a factor-flow perspective, focusing on economic, cultural, and transportation connections. We found that (1) Nanjing, which has long been ranked first, shows a downward trending score, dropping from 0.956 in 2017 to 0.937 in 2023; (2) The comprehensive first-degree spatial structure of metropolitan-area cities presents a network hierarchical development feature of "one core, multiple centres, and multiple areas". With Nanjing as the regional core city, Chuzhou (0.879), Yangzhou (0.915), and Wuhu (0.897) as sub-centre cities, and other cities as sub-regional nodes, the urban system structure gradually forms; (3) The indicators of economic (0.166 **), cultural (0.226 **), and transportation (0.644 ***) element connections were interrelated and mutually reinforced, forming a unified entity with internal connections. This study quantitatively measured the level of integrated development in the Nanjing metropolitan area and provided a reference for formulating regional policies.

Keywords: urban primacy index; Nanjing metropolitan area; evolution of spatial pattern; endogenous mechanisms; geospatial regression analysis

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1. Introduction

In recent years, the rapid development of information technology and transportation infrastructures has significantly improved the mobility of various elements between cities [1]. In the process of global integration, China's core big cities, such as Shanghai, Beijing, and Shenzhen, continue to develop and become important nodes in regional aviation, information, and financial networks, leading surrounding city clusters to participate in the division of labour and competition in the global economy [2]. Within urban agglomerations, the isolation effect of administrative divisions is gradually being broken, and the scope of the external functional radiation of regional central cities is constantly expanding. At the same time, they also face the challenge of the passive diversion of resource elements. Improving the primacy of central cities has become an important measure for promoting high-quality regional development [3]. Urban primacy refers to the population ratio of the largest and second-largest cities in a region [4]. This indicator is also commonly used to measure urban population size and development stage [5]. There have been many international research achievements regarding the primacy of cities, but few studies have evaluated the primacy of cities within a region by measuring the strength of the resource element connections between them [6].

Research into the theory of urban agglomerations has long been conducted, but it has mainly involved the definitions of urban agglomerations, spatial structures, and the

evolution process [6]. Chinese scholars have focused on theoretical research into urban agglomerations in terms of functional positioning, development planning, and formation models [7]. Some scholars believe that small cities within metropolitan areas are interconnected through central cities to build regional urban networks jointly [8]. Additionally, other cities within the metropolitan area play the roles of external functional coordination and central city element connections [9]. From a conceptual definition perspective, the United States first proposed the concept of metropolitan areas in 1910, followed by French geographers who subsequently proposed similar concepts such as the "metropolitan belt" and "metropolitan continuous belt" [10]. After the 1950s, Japanese scholars proposed relevant theories on urban regional differentiation, forming the initial concept of "and metropolitan areas" [11]. This concept has evolved continuously and has become the theoretical basis for the current concept of metropolitan areas [12]. Scholars have defined an urban agglomeration as a geographical area that can receive certain functional services from the central city daily. The population size of a central city must exceed 100,000 [13]. With continuous improvements in high-speed railway networks, transportation connections between cities within metropolitan areas have become more convenient. Some studies have also defined metropolitan areas as those that can be reached within a one-hour commuting time range, with the central city as the core [14]. Currently, international research on the spatial structure of urban agglomerations mainly focuses on three aspects: the form [6], the evolution process [7], and the mode of element organisation [8]. Overall, there is a lack of research into the spatial structure of urban agglomerations, both domestically and internationally, and related theoretical research lags behind social practice [14].

Urban spatial governance within a region is an important research direction in urban agglomerations [15]. Research into regional spatial governance has focused on exploring the relationship between urban elements and spatial evolution processes within urban agglomerations under market conditions [16]. International research on regional governance focuses on carrying out urban agglomeration governance through policy formulation, departmental cooperation, and multiparty linkages, ultimately achieving regional coordinated development [17]. Scholars have compared the management models of urban agglomerations in China with those in the United States and believe that regional management models and structures conforming to the national political system are important guarantees for supporting regional economic development [18]. With the acceleration of urbanisation, China's large urban agglomerations have rapidly expanded in scale. Research on urban agglomerations has focused on planning and construction [19], international experience [20], ecological environment governance [21], industrial coordinated development [22], equalisation of basic public services [23], and collaborative governance level measurements [24]. Spatial governance policies in urban areas relate to formulating reasonable spatial development plans, strengthening element connections, optimising spatial structures, and establishing a unified and orderly governance mechanism [25]. Overall, Chinese scholars have focused their research on regional collaborative governance policies, whereas there are relatively few studies on governance models from the perspective of urban factor connections [26].

Previous studies have revealed the functional types and positioning of central cities through the index of urban primacy within a region and proposed strategic paths for coordinated development between regional central and surrounding cities [27]. Scholars have used the first-degree index to measure regional economic growth and urban size distribution levels, screening indicators that expand from the population to fields such as the economy, industry, technology, and culture. The indicator system is constantly expanding [28]. Scholars have extended the concept of primacy by dividing it into element types and using the Analytic Hierarchy Process to determine specific weights [29]. With China's rapid urbanisation, the administrative divisions of cities have been continuously adjusted, coordinated management of surrounding cities has been implemented, and their regional influence at the administrative system level as been expanded. Scientifically, understanding and measuring the primacy index of regional central cities has become

an important topic for all sectors of society [30]. In fact, international research on urban primacy has already broken through the single-dimensional indicator of population, paying more attention to external functional radiation and cities' factor connections, as well as the synergistic driving effect on other cities in the region [31]. However, empirical research that measures urban primacy indicators from the perspectives of factor flow, regional resource agglomeration, and distribution patterns is lacking [32].

At present, the analysis of urban primacy mostly uses statistical yearbook indicators, such as population size and economic total, for calculations. These are difficult to match with the current high-speed flow of factors between cities, and they cause a serious lag in local practices. The concept of urban primacy has shifted towards the radiative driving effect of primacy cities in surrounding areas. Primacy is seen as a policy tool for understanding and regulating the direction of urban socioeconomic development, thereby enhancing the city level. Therefore, we believe that urban primacy, as a comprehensive indicator of the position of a city in a region, cannot be measured simply using one or two indicators. It must be evaluated by constructing a scientific indicator system [14,18]. This indicator system should not only combine the traditional connotation of urban primacy, but should also consider the transformation trend of China's new urbanisation from speed-driven to quality-driven and from scale expansion to connotation-based operation [22].

This study aims at regional collaborative development and constructs a comprehensive evaluation index system for the primacy of central cities from the perspective of factor flow space, quantitatively measuring the level of intercity factor connections. By comparing the first-degree change data for multiple years from 2017 to 2023, we analysed the trend of changes in the external functional positioning and functional connections of each city within the metropolitan area and proposed corresponding regional development strategies. The research results break through the existing administrative division governance pattern of urban agglomerations, combining the evaluation of urban primacy with the optimisation of urban agglomeration structure and proposing a regional collaborative governance model supported by elements such as economic connections, resource sharing, and project co-construction [33]. Specifically, this study expands the traditional evaluation model that only considers the population as a single indicator and constructs an indicator system consisting of six dimensions: urban scale, comprehensive economy, scientific and technological talents, industrial development, public services, and opening up to the outside world. This indicator system is used to measure the comprehensive primacy of central cities within the metropolitan area, identify the characteristics of resource agglomeration and factor flow between cities within the metropolitan area, and propose coordinated development strategies for various cities within the region.

2. Materials and Methods

2.1. Study Area

The Nanjing metropolitan area is a regional economic community centred around Nanjing, located in the core area of the urban agglomeration along the middle and lower reaches of the Yangtze River in eastern China. The geographical scope of the Nanjing metropolitan area includes Jiangsu and Anhui provinces, making it the first cross-provincial planning and construction metropolitan area in China [32]. According to the "Development Plan for Nanjing Metropolitan Area", the geographical scope of the Nanjing metropolitan area includes eight cities, including Nanjing, Zhenjiang, Yangzhou, Huai'an, Wuhu, Ma'anshan, Chuzhou, and Xuancheng, as well as Jintan and Liyang in Changzhou. There are a total of 33 municipal districts, 11 county-level cities, and 16 counties, with a total area of 66,000 square kilometres [32]. By 2023, the permanent population of the Nanjing metropolitan area was approximately 35.3176 million. The permanent urban population is approximately 25.9281 million, and the urbanisation rate of the permanent population is approximately 73.41%. The scale and volume of the city is approximately CNY 4175.078 billion, with primary, secondary, and tertiary industries accounting for 4.67%, 42.45%, and 52.88%, respectively. The social and economic elements within the Nanjing metropolitan

area are generally highly interconnected, and the flow of personnel, materials, and other elements between cities is convenient. It is an important sector that provides social and economic connections between the eastern and western regions of China [33] (Figure 1).

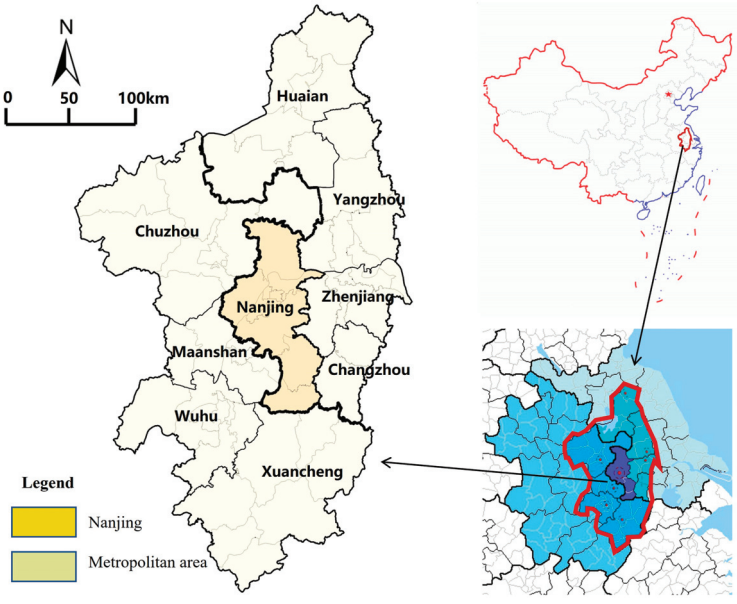


Figure 1. Location of Nanjing Metropolitan Area.

The Nanjing metropolitan area is the first inter-provincial collaborative metropolitan area in China and one of the three major metropolitan areas on which the Jiangsu Provincial Government has focused [34]. The travel time between cities within the metropolitan area, also known as the Nanjing one-hour metropolitan area, is just over an hour [35]. The Nanjing metropolitan area is a city cluster closely connected by a developed transportation network, rather than a fixed area with an actual administrative management authority [36]. On the other hand, the Nanjing metropolitan area is a cross-provincial urban agglomeration that includes some cities from Jiangsu and Anhui provinces. It is a regional economic belt formed around Nanjing, with cities working and developing together (Table 1).

Table 1. Nanjing's metropolitan area's population and urbanisation rates in different years.

	Registered Residence Population (10,000 People)			**Permanent Population (10,000 People)**			**Urbanization Rate of Permanent Residents (%)**		
	2017	**2020**	**2023**	**2017**	**2020**	**2023**	**2017**	**2020**	**2023**
Nanjing	697	738	792	733	812	894	71	78	82
Changzhou	382	418	435	421	462	488	74	79	83
Huai'an	562	589	632	592	631	667	62	70	75
Yangzhou	462	492	531	499	527	558	68	74	77
Zhenjiang	273	298	322	322	349	382	72	76	82
Xuzhou	456	483	521	413	433	457	56	64	73
Ma'anshan	231	267	298	242	287	312	69	73	78
Wuhu	391	432	467	378	392	413	67	72	77
Xuancheng	287	312	336	297	303	328	52	58	62
Total	3741	4029	4334	3897	4196	4499	67	72	79

2.2. Materials

2.2.1. Data Collection

This study focuses on nine prefecture-level cities in the Nanjing metropolitan area and obtains basic data through various channels. The content includes the city statistical yearbook, land use vector data, road network vector data, 30 m resolution remote sensing image data, and TERG-DEM digital elevation data from 2017, 2020, and 2023, all of which were obtained from the Chinese Academy of Sciences geospatial data cloud platform (https://www.gscloud.cn/, accessed on 22 July 2023). First, we spatially mapped the urban administrative boundary vector data, road vector data, and third land use survey data using the National 2000 Geodetic Coordinate System and Gaussian Kriging Projection to complete the data fitting (Table 2). Second, we cross-validated the accuracy of the urban land use survey results, including land use types and other attributes, by comparing high-resolution remote sensing images. Finally, we divided the land use types within the metropolitan area into six categories, including forest land, garden land, cultivated land, water bodies, construction land, and others.

Table 2. Data types and structure required for research.

Data Type	Data Content	Data Volume (10,000 Pieces)	Acquisition Year	Data Source
Land-use Data	Land-use Vector Data	1.7	2017, 2020, 2023	Chinese Academy of Sciences Geospatial Data Cloud
	TERG-DEM Digital Elevation Data	/		
	Landsat 8 Satellite Remote Sensing Image Data	/		
Urban Facility Data	Base Map of Urban Architecture	13.15		OpenStreetMap Data Platform (OSM)
	Urban Road Network (including expressways, main roads, and secondary roads)	0.8		
Statistical Yearbook	China Urban Statistical Yearbook, Jiangsu Provincial Statistical Yearbook, Anhui Provincial Statistical Yearbook	0.1		Urban Public Service Data Platform

2.2.2. Variables and Indicators

We constructed six primary indicators: economic, cultural, transportation, urban scale, public services, and level of openness to the outside world. The indicator system classified and measured the linkage levels of production factors, urban functions, health and library infrastructures, and other aspects between cities. We drew on existing research results and refined the decomposition of the primary indicators, dividing them into 17 secondary indicators [37]. Urban-scale indicators included two secondary indicators: population size and built-up area. The economic factor relationship included four indicators: annual GDP), fixed asset investment quota, trade exchange index, and investment and financing indices. Cultural element connection included three indicators: the number of academic conferences, art exhibitions, and science and technology exhibitions hosted. The transportation element connection included three indicators: daily high-speed rail trips, intercity bus trips, and intercity subway connectivity. Health and Libraries Infrastructure level was measured by indicators such as the number of public book collections and beds in health institutions, whereas the level of opening up to the outside world was measured by indicators such as the actual use of foreign investment, total import and export volumes, and tourism foreign exchange income (Table 3).

Previous research suggests that regional integration emphasizes proximity effects, regional connectivity, and efficiency improvement, which are reflected in the complementary functions and rational division of labor between different cities [13,21]. This article conducts a first-degree analysis of the Nanjing metropolitan area, focusing on measuring the flow level of economic, cultural, transportation, and other resources between different cities. Some studies suggest that regional transportation network infrastructure is the foundation for the connection of various resource elements, and the connection of various types of

elements such as cultural resources, economic resources, and public service resources is a concrete manifestation of the urban connectivity degree [21,25]. We will supplement more indicators in subsequent research to reflect regional development trends such as green, low-carbon, and sustainable. These indicators include the level of technological innovation, green development, etc., which more comprehensively reflect the overall development level of the region.

Table 3. The Index System for the Urban Comprehensive Primacy Index.

Primary Indicators	Secondary Indicators
Economic element connection (X11)	Annual gross domestic product (X111) Fixed assets investment (X112) Trade exchange index (X113) Investment and financing index (X114)
Cultural element connection (X12)	Number of academic conferences hosted annually (X121) Number of art exhibitions hosted annually (X122) Number of science and technology exhibitions hosted annually (X123)
Transportation element connection (X13)	Number of daily high-speed rail trips (X131) Number of daily intercity bus trips (X132)
Urban scale (X14)	Total population size (X141) Built-up area (X142)
Health and libraries infrastructure (X15)	Number of books in public libraries (X151) Number of beds in medical institutions (X152)
Foreign capital utilization (X16)	Actual amount of foreign investment used (X161) Total import and export volume (X162) Tourism foreign exchange income (X163)

2.3. Methods

2.3.1. Entropy Weighting Method

Commonly used objective weighting methods include the entropy weighting, coefficient of variation, and principal component analysis methods [38]. This study uses the entropy weighting method to weight indicators. The entropy weight method is based on the difference-driven principle combined with the original information of the indicators, and it determines the weight of the indicators based on the information entropy of each indicator [39]. This method can effectively avoid the interference caused by subjective judgments and ensure objective consistency in obtaining the weights for each indicator. During the calculation process, we normalised and standardised the data to eliminate dimensional differences among various indicators, making a horizontal comparison between multiple indicators easier.

The standardisation formula for positive correlation indicators is as follows:

$$F_{ij} = \left(x_{ij} - x_{min}\right) / \left(x_{max} - x_{min}\right) \quad (1)$$

The standardisation formula for negative correlation indicators is as follows:

$$F_{ij} = \left(x_{max} - x_{ij}\right) / \left(x_{max} - x_{min}\right), \quad (2)$$

where x_{ij} is the current value of the i-th object and the j-th indicator. F_{ij} is the standardised value of the j-th indicator of the i-th object, and $F_{ij} \in [0, 1]$. x_{max} is the maximum value of the jth indicator group. x_{min} is the minimum value of the jth indicator group. We calculated the feature proportion ($i = 1, 2, \ldots, n$) of the i-th evaluation object under the j-th indicator ($j = 1, 2, \ldots, n$) using the following formula:

$$p_{ij} = F_{ij} / \sum_{i=1}^{n} F_{ij}. \quad (3)$$

We calculated the entropy value of the indicator as:

$$e_j = -k\sum_{i=1}^{n} p_{ij} ln p_{ij}. \quad (4)$$

Among these, $k > 0$, $e_j > 0$, $k = 1/lnn$. We calculated the coefficient of difference for indicators as:

$$g_j = 1 - e_j. \quad (5)$$

The comprehensive weight of indicators was calculated thus:

$$\omega_j = g_j / \sum_{j=1}^{p} g_j. \quad (6)$$

Among these, ω_j was the normalised weight coefficient.

2.3.2. Element Flow Analysis Method

With the continuous expansion of the urban scale, various socioeconomic factors flow rapidly between cities, driving economic and trade connections in surrounding cities, which manifests as the core function of the central city [40]. We measured the characteristics of the urban spatial structure and outwards connectivity function from the perspective of factor flow, including the efficiency of urban external service output and the level of foreign trade [41]. Based on this, we measured the spatial structural characteristics of the external element connections of various cities within the Nanjing metropolitan area, as well as the differences in the degree of outwards orientation among cities within the metropolitan area.

Various urban factors drive the economic development of urban agglomerations. Urban factor flows include factors and resources such as population, information, technology, and capital flows. We defined the intensity of urban flow as the level of external factor connectivity among cities within a metropolitan area. Taking economic flow as an example, we chose the gross domestic product and import and export trade volume of the secondary and tertiary industries in cities as measurement indicators of economic and social factor flow in urban agglomerations. The formula used was

$$Q_{ij} = \frac{e_{ij}/e_i}{E_j/E}. \quad (7)$$

Among these, Q_{ij} represents the outwards function of the city, and e_{ij} and e_i represent the gross domestic products of industry j and the gross domestic product of city i. E_j and E represent the gross domestic product (GDP) of the j-th industry in the metropolitan area and the GDP of the metropolitan area, respectively. If $Q_{ij} \leq 1$, then there is no correlation between the gross domestic product of the j industry in city i and foreign trade. At this point, $e_{ij} = 0$. The gross domestic product (GDP) of industry j-th in city i mainly refers to foreign trade services that provide products and services to the outside world. Therefore, $E_{ij} = e_{ij} - e_i(E_j/E)$, and the total outwards functional connections of city i are:

$$E_i = \sum_{i=1}^{n} E_{ij}. \quad (8)$$

The urban flow model is $F = NE$, where F represents the intensity of economic and social factor flows, N represents the efficiency of urban functions, and E represents the total number of outwards functions. We use per-capita GDP to represent urban functional efficiency. Then, $N_i = GDP_i/e_i$ and the socioeconomic factor flow is

$$F_i = N_i E_i = \left(\frac{GDP_i}{e_i}\right) E_i = GDP_i\left(\frac{e_i}{E_i}\right) = k_i GDP_i. \quad (9)$$

In the formula, k_i represents the ratio of the total foreign trade quota of city i to the total industrial output of all the cities in the metropolitan area. This value reflects the

difference in the degree of foreign trade between the total industrial output of city *i* and the metropolitan area, indicating a tendency for urban flow.

2.3.3. Geospatial Regression Analysis Method

This study uses a geospatial regression model to measure the economic differences between cities within the metropolitan area, and the coefficient of variation as a measurement indicator to analyse the differences in economic element connections between cities within the metropolitan area at different time periods. Geographically weighted regression is an extension of ordinary linear regression models that embeds the spatial position of data into regression equations in the following form:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \quad i = 1, 2, 3 \ldots, n. \tag{10}$$

In the formula, (u_i, v_i) is the coordinate of sampling point i, and $\beta_k(u_i, v_i)$ is the k-th regression parameter on sampling point *i*. During the estimation process, the geographic location was determined using the weight function method. The formula used to calculate the coefficient of variation is as follows:

$$CV = \frac{1}{X}\left[\frac{1}{n}\sum_{i=1}^{n}(X - X_i)^2\right]^{1/2}, \tag{11}$$

where CV is the coefficient of variation. X and X_i represent the per capita GDP of each city within the Nanjing metropolitan area and the per capita GDP of city *i* and n is the number of cities in the study area.

3. Results

3.1. Nanjing Has Long Been First in the Comprehensive Ranking, but Its Score Shows a Fluctuating Downward Trend

For indicator selection, we used the entropy weight method to measure the specific weights of the urban primacy indicators, as shown in Table 4. Among them, the number of permanent residents, built-up area, and amount of fixed asset investment are the three indicators with the highest priority weight, representing the scale and carrying the city's capacity. Second, indicators such as economic and trade relations, transportation element relations, and cultural element relations represent the level of main urban functions and external functional relations with correspondingly high weights.

Table 4. The weights of various measurement indicators for urban comprehensive primacy.

Indicator Items	Information Entropy (e)	Information Utility (d)	Weight (%)
Annual gross domestic product (X111)	0.912	0.097	4.323
Fixed assets investment (X112)	0.843	0.089	3.672
Trade exchange index (X113)	0.947	0.117	3.166
Investment and financing index (X114)	0.782	0.104	3.018
Number of academic conferences hosted annually (X121)	0.793	0.114	2.132
Number of art exhibitions hosted annually (X122)	0.839	0.095	2.189
Number of science and technology exhibitions hosted annually (X123)	0.872	0.093	2.272
Number of daily high-speed rail trips (X131)	0.854	0.131	2.301
Number of daily intercity bus trips (X132)	0.817	0.118	2.351
Total population size (X141)	0.854	0.133	3.007
Built-up area (X142)	0.782	0.093	3.072
Number of books in public libraries (X151)	0.793	0.097	3.351
Number of beds in medical institutions (X152)	0.805	0.127	2.121
Actual amount of foreign investment used (X161)	0.791	0.118	2.054
Total import and export volume (X162)	0.786	0.097	2.378
Tourism foreign exchange income (X163)	0.722	0.083	2.733

We used the above indicator system to conduct subitem calculations on the primary indicators of the central cities within the metropolitan area. Taking Nanjing as an example, we calculated the scores of 17 secondary indicator categories, with an urban primacy index

score ranging from 1 to 5 points. We also conducted a horizontal comparison of the indicator values for three years (2017, 2020 and 2023). We used statistical yearbook data and entropy weight analyses to measure the primacy index and normalise the sub primacy index. The results are summarised in Table 5. As the core city of the metropolitan area, Nanjing's comprehensive urban primacy index has been continuously decreasing over the past six years, from 3.7 in 2017 to 3.3 in 2023, indicating that the radiation impact of the central city on the surrounding areas has weakened. In addition, the urban primacy index of economic factor linkage has also decreased from 2.9 in 2017 to 1.7 in 2023, marking a significant decline in the scale of trade exchanges and investment and financing between Nanjing and surrounding cities. The urban primacy index of cultural element connections showed no significant fluctuations over the six-year period, maintaining at approximately 3.4 points. As a resource centre in the political, economic, and cultural dimensions of the region, Nanjing has an absolute advantage in the configuration of large venues and facilities. The corresponding number and scale of events such as academic conferences, art exhibitions, and science and technology exhibitions also demonstrate obvious advantages [33].

Table 5. Ranking scores of sub items for Nanjing metropolitan area's central cities in 2017, 2020, and 2023.

Primary Indicators	Secondary Indicators	Nanjing/Yangzhou		
		2017	2020	2023
Economic element connection (X11)	Annual gross domestic product (X111)	1.2	1.2	1
	Fixed assets investment (X112)	4.4	1.4	1.3
	Trade exchange index (X113)	3.8	3	2.7
	Investment and financing index (X114)	2.5	2.4	2.1
	Subtotal	2.9	1.9	1.7
Cultural element connection (X12)	Number of academic conferences hosted annually (X121)	0.8	0.8	0.7
	Number of art exhibitions hosted annually (X122)	2.2	1.4	1.4
	Number of science and technology exhibitions hosted annually (X123)	3.6	2.3	2.3
	Subtotal	2.2	1.5	1.5
Transportation element connection (X13)	Number of daily high-speed rail trips (X131)	3.2	2.8	3.1
	Number of daily intercity bus trips (X132)	4.9	4.8	4.8
	Subtotal	3.4	3.5	3.4
Urban scale (X14)	Total population size (X141)	1.8	1.8	1.8
	Built-up area (X142)	4.3	3.1	2.8
	Subtotal	2.3	1.9	1.9
Health and libraries infrastructure (X15)	Number of books in public libraries (X151)	1.8	2.1	1.8
	Number of beds in medical institutions (X152)	5.3	3.1	3.4
	Subtotal	3.6	3.3	3.3
Foreign capital utilisation (X16)	Actual amount of foreign investment used (X161)	1.4	1.5	1.6
	Total import and export volume (X162)	5.7	0.9	1.5
	Tourism foreign exchange income (X163)	3	6.5	3.3
	Subtotal	3.6	3.4	3.1
Comprehensive primacy value		3.7	3.5	3.3

3.2. The Comprehensive Primary Index Ranking Score Presents the Spatial Structure of "One Core, Multiple Centres"

We measured the comprehensive primacy index of eight major cities within the metropolitan area using the above method and normalised the scoring dimension. We sorted the comprehensive first-place index of each city in 2017, 2020, and 2023, and the results are shown in Table 6. As the capital city of Jiangsu Province, Nanjing consistently ranks first in terms of social and economic factors. The comprehensive first-degree indices for the three years were 0.956, 0.931, and 0.937, respectively. Although the first-degree score decreased slightly, it consistently ranked first in metropolitan areas. As a national historical and cultural city, Yangzhou has a leading level of social and economic development in the region and has long ranked second in terms of urban agglomeration. Except for the first two rankings, the priority ranking of subsequent cities shows a fluctuating trend over time, which is consistent with various city attributes and socioeconomic development stages.

Table 6. Ranking of top cities in the Nanjing metropolitan area in 2017, 2020, and 2023.

Rank	City List	Comprehensive Primacy Value (2017)	City List	Comprehensive Primacy Value (2020)	City List	Comprehensive Primacy Value (2023)
1	Nanjing	0.956	Nanjing	0.931	Nanjing	0.937
2	Wuhu	0.916	Yangzhou	0.908	Yangzhou	0.915
3	Huai'an	0.893	Wuhu	0.875	Wuhu	0.897
4	Zhenjiang	0.721	Xuancheng	0.839	Chuzhou	0.879
5	Ma'anshan	0.738	Zhenjiang	0.812	Huai'an	0.831
6	Chuzhou	0.702	Huai'an	0.773	Zhenjiang	0.779
7	Yanghzou	0.682	Ma'anshan	0.708	Ma'anshan	0.754
8	Xuancheng	0.677	Chuzhou	0.684	Xuancheng	0.662

We conducted a spatial mapping of the primary ranking indicators of major cities within the metropolitan area in 2017, 2020, and 2023. The 2017 data suggested the metropolitan area is centred around Nanjing, including the sub-regional centres of Wuhu and Huai'an. The Wuhu subregion includes several cities such as Wuhu, Ma'anshan, Xuancheng, and Chuzhou. The Huai'an sub-region includes the entire Huai'an region and some areas in the northern part of Yangzhou, and the urban primacy index pattern of the urban agglomeration presents a "multi core" distribution feature. However, with the acceleration of Nanjing's urbanisation, the resources of the cities surrounding Nanjing are constantly gathered towards the central city. Compared to the data from 2020, the top three cities with the highest ranking within the metropolitan area are more clustered, exhibiting a typical "single core" distribution characteristic. With the continuous strengthening of urban and external functional connections in Nanjing, its status as a regional city centre has significantly improved. In 2023, the spatial characteristics have emerged, with Chuzhou, Yangzhou, and Wuhu as sub-centres, and the Nanjing metropolitan area has gradually shown an urban primacy index spatial distribution pattern of "one main and multiple sub centres" (Figure 2).

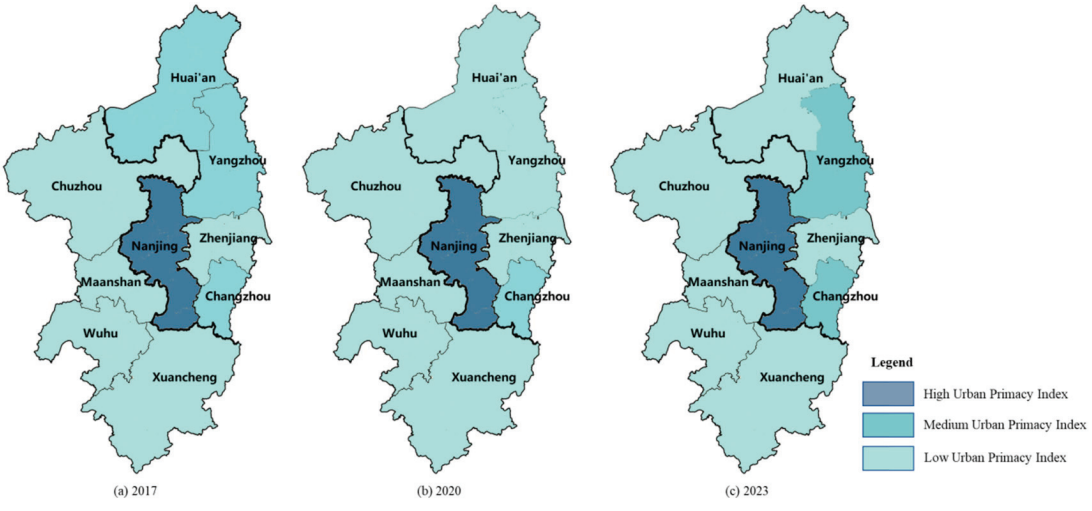


Figure 2. Evolution of the spatial distribution pattern of comprehensive urban primacy index in the Nanjing metropolitan area.

Through the analysis of the superior and inferior distance method, the results indicate that the Nanjing metropolitan area presents a spatial characteristic of "one core and three centres", which can be used to construct a regional cluster with Nanjing as the core city and Chuzhou, Yangzhou, and Wuhu as the sub-centre cities (Figure 3). The metropolitan area is centred on Chuzhou as a sub-regional city, connecting the northern region of Anhui to the west. Taking Wuhu as the sub-regional central city, it connects the southern regions of

Anhui, such as Ma'anshan and Xuancheng Cities, to the west. Taking Yangzhou as the sub-regional centre city, it has a northward functional connection with northern Jiangsu areas such as Huai'an and Suqian. This is similar to existing research results, which have found that the geographical spatial pattern and element distribution of the Nanjing metropolitan area generally exhibit a "one core, multiple poles" characteristic [21,25,30].

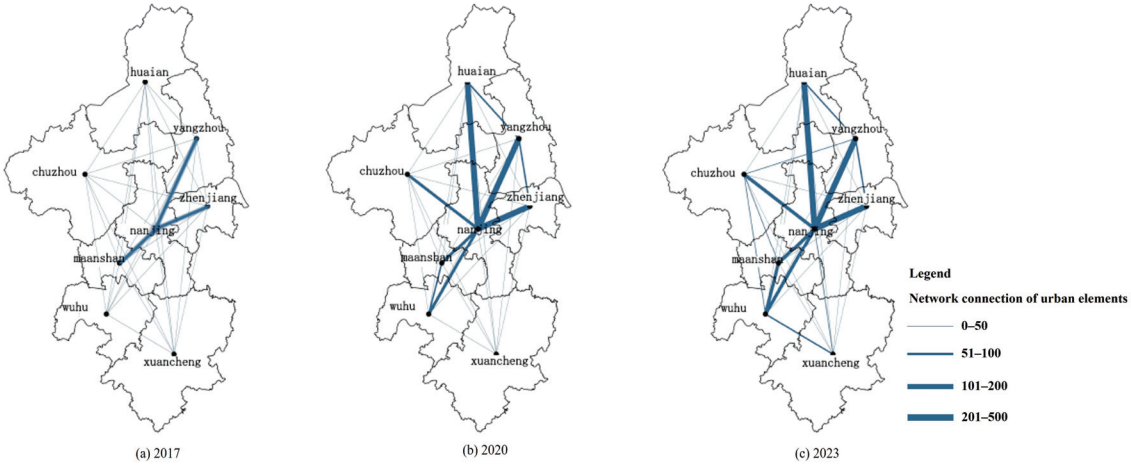


Figure 3. Evolution of the distribution pattern of element connections between cities in the Nanjing metropolitan area.

3.3. The Element Connections between the Central City and Surrounding Cities Exhibit Spatiotemporal Heterogeneity Characteristics

We spatially mapped indicators such as economic, transportation, and cultural element connections among cities within the metropolitan area, as shown in Figure 4. The overall spatial pattern conforms to "one core, multiple centres, and multiple areas". Among these, "one core" refers to the scope of Nanjing City. As the capital city of Jiangsu Province, Nanjing has significant advantages in public services, regional transportation, financial trade, cultural tourism, and other aspects in terms of level and quantity. "Multiple centres" refer to areas around Nanjing, including Yangzhou City in the northeast and some parts of Chuzhou City in the west. These areas have relative advantages in terms of economy, culture, and transportation, which can drive functional complementarity and element connections between cities in surrounding subregions. In addition, cities along the Yangtze River had a relatively high degree of primacy. As an important waterway transportation channel, the Yangtze River facilitates convenient, inexpensive, and efficient transportation of resource elements in cities along the route. "Multiple districts" refer to the secondary areas on the east, west, and south sides of Nanjing, where the elements are relatively closely connected. The connections between cities within the region are closer than those outside the region, and the central city serves as a hub to drive the connections between cities within the region.

3.4. The Endogenous Mechanism of the Comprehensive Primacy Distribution Patterns of Metropolitan Areas

The VAR model is a commonly used econometric model [22]. The VAR model regresses several lagged variables for all variables using all current variables in the model. The VAR model is suitable for stationary multi-time series data, such as the E-G cointegration test and the error correction model (ECM) for single equations. For non-stationary multi-time series data, Johansen cointegration and vector error correction models (VECM) can also be established. We constructed a Vector Autoregressive (VAR) analysis model and stationarity tests on the indicator variables used in this paper. The model follows the LLC criterion;

sets the lag order of the VAR model to two; measures evaluation statistics such as AIC, SC, and LR; uses Johansen's method for cointegration testing. The trajectory statistics and maximum eigenvalue test values in Table 7 indicate that the six sets of urban element connection vectors we set did not pass the cointegration test, and there was no cointegration relationship. Thus, they are unsuitable for constructing a modified VECM. Meanwhile, all first-order differential sequences passed the cointegration tests; therefore, they were more appropriate for constructing a VAR model for the first-order differential.

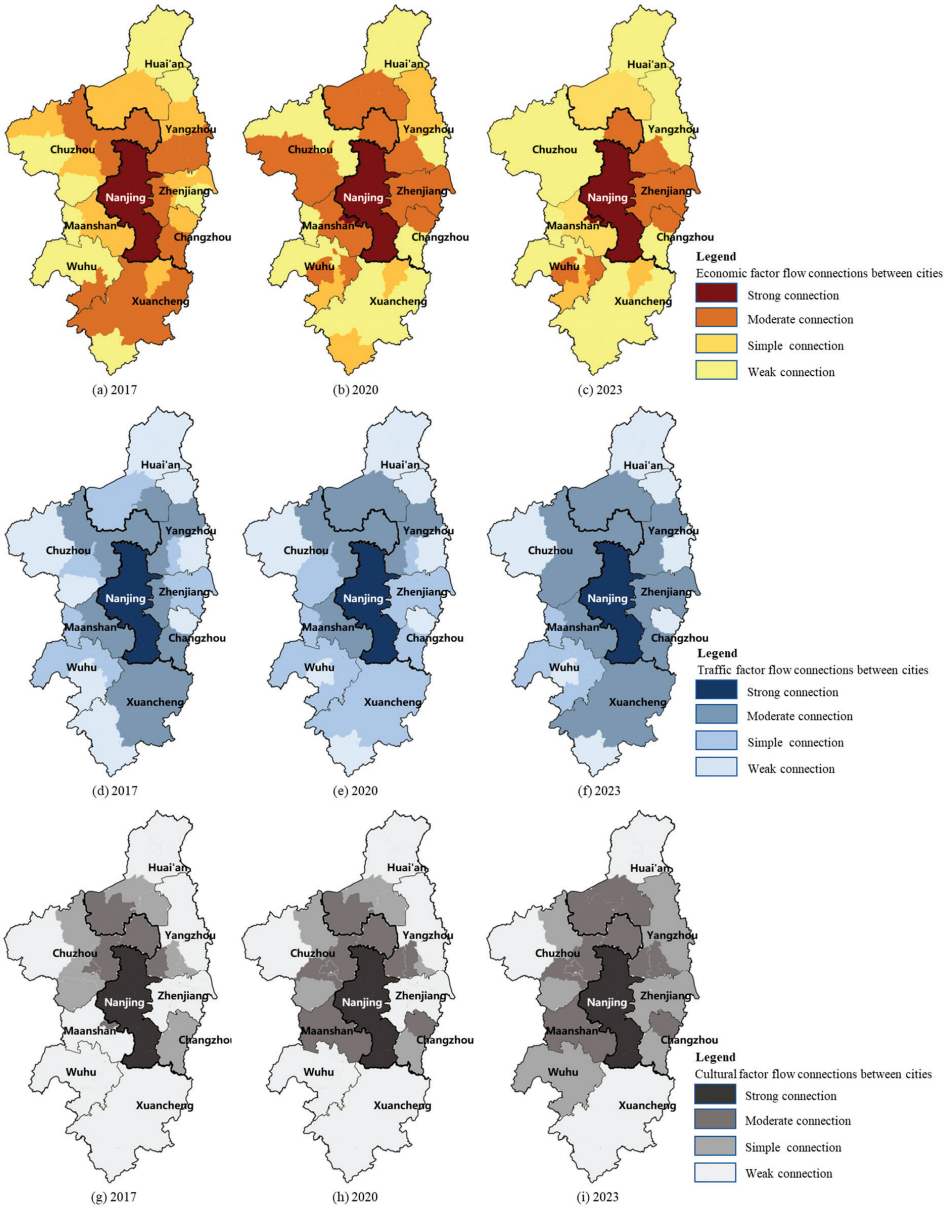


Figure 4. The evolution of the distribution pattern of economic flow, cultural flow, transportation flow, and other elements in the Nanjing metropolitan area.

Table 7. The co-integration test of the VAR model for inter-city factor connections.

Vector	Null Hypothesis	Eigenvalues	Trajectory Statistics	5% Critical Value	*p*-Value
Annual gross domestic product (X111)	None	0.398	10.355	15.494	0.07 *
	Atmost 1	0.204	3.191	3.861	0.05 **
Fixed assets investment (X112)	None	0.357	8.371	15.431	0.01 ***
	Atmost 1	0.142	2.137	2.987	0.72
Trade exchange index (X113)	None	0.317	8.632	16.175	0.26
	Atmost 1	0.148	2.089	3.177	0.05 **
Investment and financing index (X114)	None	0.377	9.128	14.977	0.24
	Atmost 1	0.158	3.145	2.989	0.06 *
Number of academic conferences hosted annually (X121)	None	0.357	7.362	13.498	0.31
	Atmost 1	0.187	2.563	2.732	0.07 *
Number of art exhibitions hosted annually (X122)	None	0.318	8.277	14.956	0.23
	Atmost 1	0.139	2.361	2.787	0.05 **
Number of science and technology exhibitions hosted annually (X123)	None	0.372	8.101	15.304	0.27
	Atmost 1	0.144	2.312	2.733	0.03 **
Number of daily high-speed rail trips (X131)	None	0.357	7.362	13.498	0.31
	Atmost 1	0.187	2.563	2.732	0.07 *
Number of daily intercity bus trips (X132)	None	0.318	8.277	14.956	0.23
	Atmost 1	0.139	2.361	2.787	0.05 **

Note: The smaller the *p*-value, the lower the probability of the original hypothesis occurring. According to the principle of small probability, we have reason to reject the original hypothesis. *** represents $p < 0.01$, ** represents $p < 0.05$ and * represents $p < 0.1$.

We further conducted unit root tests on various indicators of the VAR model, and the test results are presented in Table 8. The original sequence index was non-stationary, but it passed the integration test. The various indicators of the first-order differential variables were stationary sequences, and the model results verify the rationality of constructing a first-order differential VAR model.

Table 8. The unit root test of comprehensive primacy index for each city.

Vector	Original Sequence Test ($\alpha = 0.05$)			First Order Difference Test ($\alpha = 0.05$)		
	ADF-Value	*p*-Value	State	ADF-Value	*p*-Value	State
Annual gross domestic product (X111)	−3.071	0.054	Non-stationary	−6.327	0.001	Stationary
Fixed assets investment (X112)	−2.437	0.156	Non-stationary	−4.237	0.006	Stationary
Trade exchange index (X113)	−1.551	0.481	Non-stationary	−3.812	0.015	Stationary
Investment and financing index (X114)	−1.939	0.305	Non-stationary	−4.092	0.012	Stationary
Number of academic conferences hosted annually (X121)	−3.081	0.056	Non-stationary	−6.912	0.001	Stationary
Number of art exhibitions hosted annually (X122)	−2.381	0.156	Non-stationary	−5.789	0.001	Stationary
Number of science and technology exhibitions hosted annually (X123)	−2.791	0.237	Non-stationary	−3.782	0.001	Stationary
Number of daily high-speed rail trips (X131)	−2.636	0.182	Non-stationary	−4.072	0.001	Stationary
Number of daily intercity bus trips (X132)	−2.791	0.237	Non-stationary	−3.782	0.001	Stationary

Note: The ADF value refers to the results of the Augmented Dickey–Fuller (ADF) test. This method is used to test whether time-series data have unit roots, and it is commonly used to detect the stationarity of data.

This study used geospatial regression analysis methods to conduct factor and interaction detection to identify the mechanisms by which each indicator element affects the comprehensive primacy of the central city. From the perspective of urban functional positioning and external factors, the indicators of economic, cultural, and transportation factors are interrelated and mutually reinforced, forming a unified entity with internal connections. We adopted the Jenks natural best breakpoint classification method to stratify and classify the ten secondary indicators in these three aspects, transforming them from numerical to type variables [42]. We took the comprehensive primacy of the city as the dependent variable and the indicators of economic, cultural, and transportation factors as independent variables. We conducted factor and interaction detection through a geographic spatial regression analysis; the results are shown in Table 9.

Table 9. Detection results of the interaction between various indicator factors of urban primacy.

	X_{111}	X_{112}	X_{113}	X_{114}	X_{121}	X_{122}	X_{123}	X_{131}	X_{132}	X_{133}
X_{112}	0.7318 ***									
X_{113}	0.7697	0.5264 **								
X_{114}	0.7725	0.6924	0.5417 ***							
X_{121}	0.7592	0.6332	0.6159	0.1660 **						
X_{122}	0.7704	0.6601	0.6418	0.3772	0.2616					
X_{123}	0.7710	0.6230	0.6831	**0.4413**	0.4777	0.2266 *				
X_{131}	0.7672	0.5908	0.6795	0.4862	0.4629	0.4967	0.3824			
X_{132}	0.7755	0.6379	0.5759	0.3747	0.4545	0.4836	0.5824	0.2531 *		
X_{133}	0.7963	0.7023	0.6983	0.6933	0.7067	0.7360	0.6888	0.6726	0.6440 ***	/

Note: Values on the diagonal in the table represent the single-factor q value and significance, where * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Bold numbers indicate nonlinear enhancement, where the interaction q value between two factors was greater than the sum of the q values of the two factors. All other indicators show a dual-factor enhancement, where the interaction q value of the two factors is greater than the larger value of the two factors but less than the sum of the q values of the two factors.

The factor detection results showed that economic, cultural, and transportation factors had a significant impact on the comprehensive urban primacy index, and all secondary indicators passed the significance test. Among them, the number of daily high-speed rail trips, number of academic conferences held, and trade exchange index have the strongest impacts, whereas the number of books collected by the library, investment and financing index, annual GDP, fixed assets investment, and other indicators have a weak impact on comprehensive primacy. Interaction detection results showed that the impact of all influencing factors after the interaction was stronger than that of single factors, which manifested as dual-factor and nonlinear enhancement. The interactions among economic, cultural, and transportation factors jointly promoted urban primacy. The interaction between the economic and transportation factors was relatively high, and the nonlinear correlation effect between these two indicators was the most significant in the model. This conclusion is similar to that of existing research, which suggests that economic and cultural factors are influenced by regional transportation infrastructure. In terms of reflecting the comprehensive priorities of cities, these three indicators have significant cross-correlation [43].

4. Discussion

4.1. The Comprehensive Primacy Index Reflects the Diversity of Functional Attributes in Large Cities

The current spatial structure of the Nanjing metropolitan area exhibits the overall characteristics of single-core-driven and polarised development, with an insufficient sub-centre-level scale. The analysis of the centrality of the factor flow network shows that the Nanjing metropolitan area presents an urban hierarchical system with Nanjing as the absolute core, whereas the sub-centres represented by Wuhu and Yangzhou still exhibit a significant gap with the development of Nanjing (Figure 5). From the trend of changes in Nanjing's urban primacy index score data over the years, the indicators of the cultural element connection between the urban primacy and the public service urban primacy index were relatively stable. Although the scores decreased, the magnitude of the change was relatively small.

The urban primacy index of economic ties exhibited a significant downward trend, indicating that Nanjing's foreign economic and trade ties are gradually weakening. Compared with existing research, some scholars believe there is a difference between broad and narrow economic factor connections. The narrow concept of economic connection measurement indicators is represented by the ratio of the total economic output of two cities, whereas the broad concept of economic indicators reflects the comprehensive strength of economic development [44]. Scholars have analysed the impact of investment and consumption on Italy's economic growth [45], and some scholars have studied the primacy of Jinan's urban economy with indicators such as city size and fixed asset investment [46]. In

recent years, the primary indicators of urban scale and volume have shown a slow decline, followed by stable development.

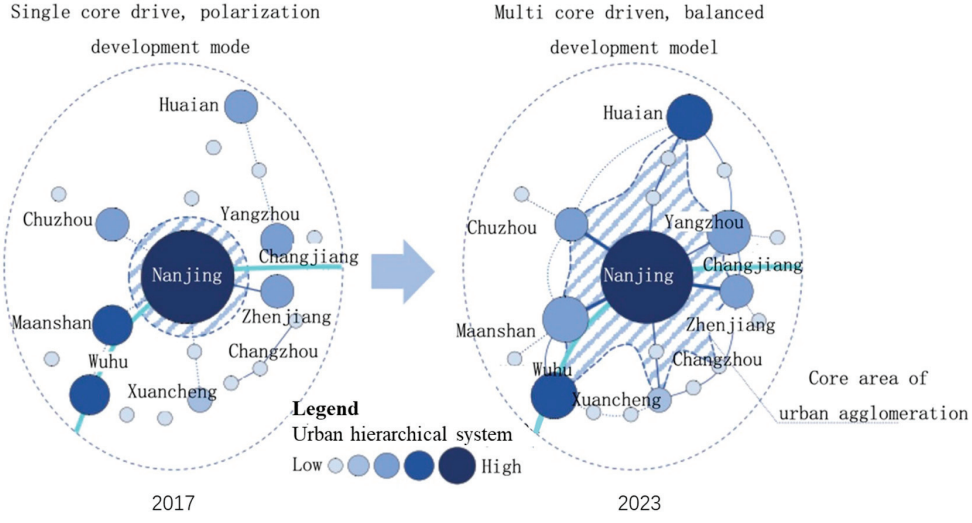


Figure 5. Schematic diagram of spatial structure optimisation in the Nanjing metropolitan area.

In recent years, the primary indicators of urban scale and volume have shown a slow decline, followed by stable development. The urbanisation rate in Nanjing increased from 62% in 2017 to 87% in 2023. Urbanisation has entered the middle and later stages, and the urban scale is becoming increasingly stable. The overall size of a city is expressed as the stage of urban development and degree of urbanisation based on its population and land use, which is also an important measurement indicator of the urban primacy index. Some scholars believe that during the rapid urbanisation process, the distribution of urban size is highly concentrated, mainly reflected in the primacy of cities [47]. Scholars have also used the populations and built-up area sizes of each urban area to reflect the primacy of urban size and have achieved relatively accurate measurement results [48]. The connection between cultural elements reflects the functional radiation and driving effect of the cultural resources of a city on surrounding cities. Scholars have studied the importance of industrial development from the perspective of structure and efficiency. Using the spatial panel Durbin model, they verified that urban primacy positively promotes economic growth and cultural industry development [49]. Research has found that the development of cultural industries has an explanatory power of 88.5% for Shanghai's economic growth, and cultural resource elements can effectively drive economic and trade connections between cities [50].

4.2. High-Level Cultural Facilities Can Effectively Drive the Flow of Urban Agglomeration Elements into the Central City

From the perspective of cultural connections, the number of academic conferences, art exhibitions, and science and technology exhibitions hosted are the most important indicators. From 2017 to 2023, the average scores of these three primary indicators in Nanjing were 3.2, 4.1, and 3.5, respectively, which was far higher than those of other cities in the urban agglomeration. This indicates that large cultural and artistic venues, science and technology exhibition halls, and other resources in the Nanjing metropolitan area were mainly concentrated in the central city, and resource allocation in surrounding cities was insufficient. The connection of cultural elements reflects a city's ability to drive external functions, such as culture, technology, and innovation. It is a concrete manifestation of its competitiveness.

Some studies suggest that the level of technological and cultural development in central cities can enhance the innovation capabilities of surrounding cities. Scholars have analysed the scientific and technological levels of each urban area in the metropolitan area and the urban primacy index of research and technological talent among practitioners. They measured the urban primacy index of urban scientific and technological innovation in Jinan from the indicator of invention patent ownership [51], and then measured the comprehensive impact of indicators such as urban scientific research expenditure, patent authorisation, and the number of students in university research institutes on urban innovation capacity [52].

We suggest that the Nanjing metropolitan area needs to improve the construction mechanism for scientific and technological talent, continuously increase scientific research investment, and attract domestic and foreign venture capital funds to join scientific research. Nanjing can utilise the R&D advantages of universities, research institutes, and research and experimental development funds to enhance its attractiveness for scientific and technological talent. At the same time, the peripheral cities of Ma' anshan, Xuancheng, and Chuzhou in the metropolitan area should be guided to establish teaching and research branches for higher schools in Nanjing within the scope of policy permission. The establishment of branch offices of research institutes in Jintan, Changzhou, Liyang, Xuancheng, and Chuzhou, where research institutes are located in Nanjing, should also be encouraged. Investments in research and development funds should be increased, and the leading and driving role of Nanjing's central city in scientific and technological innovation should be explored, while independent innovation capabilities are enhanced [53].

In Figure 6, the large circle represents the central city of the metropolitan area, the middle circle represents the potential secondary central cities within the region, and the small circle represents general small towns. Starting from the central city, taking a certain radius direction and following a simple distance attenuation rule, we drew a graph of the relationship between the influence of urban agglomerations and their spatial scope. Due to the emergence of secondary centres, the influence of urban agglomerations has rebounded far from the central city. In the same external environment, urban agglomerations with multicentre networked structures have a larger spatial range of functional radiation.

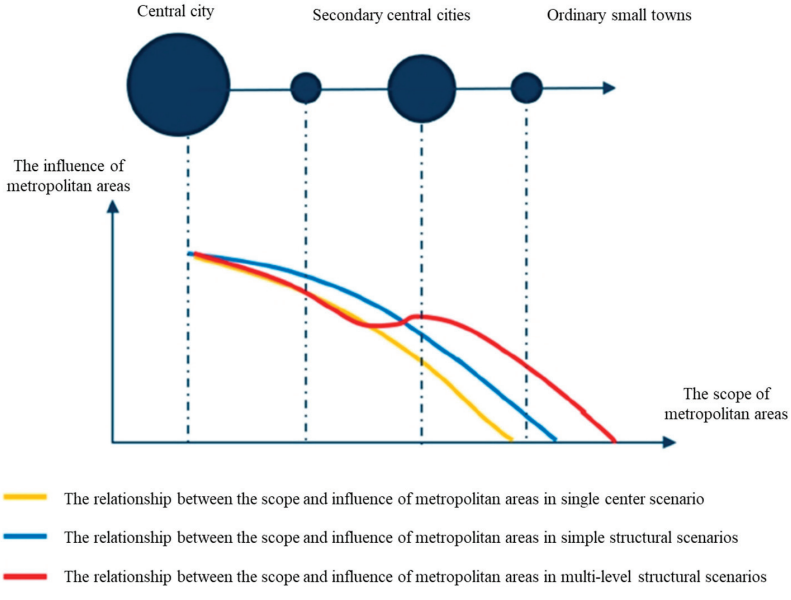


Figure 6. The functional spatial radiation range of cities of different levels within the metropolitan area.

The construction and improvement of transportation infrastructure can promote regional economic development, enhance regional accessibility, reduce transportation costs, attract investment and talent, and enhance regional economic competitiveness. For example, the construction of highways can save time costs in personnel and goods transportation, reduce trade costs, and promote productivity improvement in service and manufacturing enterprises. Meanwhile, the level of regional economic development can affect the construction and improvement of transportation infrastructure. Regions with faster economic development usually have stronger financial and technological capabilities to invest in transportation projects, thereby improving the level and efficiency of transportation services. In addition, regional culture is an important component of coordinated economic and social development, which can influence people's values, behavior patterns, and consumption habits, thereby having an impact on economic development. Therefore, regional cooperation is an important aspect of economic connections between different regions, which helps to break down barriers to the flow of production factors between regions, promote the optimal allocation of factors, and promote the realisation of regional coordinated development and spatial integration.

4.3. Positive Fiscal Policies Can Effectively Promote the Cities' Industrial Divisions within the Metropolitan Area

From 2017 to 2023, there was a significant decline in indicators, such as the trade volume index, investment and financing index, and total import and export volumes in Nanjing. This indicator first changed from high to low. The results indicate that Nanjing City does not yet have an agglomeration capacity in terms of regional economics and trade, and the metropolitan area's industrial structure and system are relatively balanced. In addition, the primacy index of fixed asset investment has remained at approximately 4.8 points for a long time, indicating Nanjing has a strong ability to gather fixed assets, such as real estate, that far exceeds that of other surrounding cities. The urban scale of Nanjing in 2023 was 1.8 trillion yuan, and the huge urban economic volume required Nanjing to build an industrial system with complementary functions and reasonable division of labour with surrounding cities. As a regional central city, Nanjing should optimise its tertiary industrial structure, gather innovative resources and high-end industrial chains, gradually withdraw from traditional manufacturing, and strengthen the layout of high-value-added industries such as innovative, financial, and cultural services [54].

In addition, studies have pointed out that the financial policies of various cities within the metropolitan area should be coordinated, and investment scales in major regional infrastructure projects and livelihood development projects should be actively carried out to continue enhancing Nanjing's central city function [55]. Other cities within the metropolitan area must seize their own resource endowment characteristics, gradually improve their social security system, increase resident income, regulate market order, create a good consumption environment, guide the diffusion and inflow of high-end consumption demand in Nanjing to surrounding cities, and drive the rational division of labour and cooperation among cities [50]. In addition, there are functional connections between cities at different levels within the metropolitan area, and the functional radiation ranges of the central and sub-central cities overlap with each other, forming a "core edge" spatial connection classification area. From Figure 7, as the scale of subcentral cities in urban agglomerations continues to increase, their functional radiation range also expands, thus compressing the functional scope of the central cities. The peripheral areas of urban agglomerations are more susceptible to the elemental connections of the subcentral regions, and the entire urban agglomeration ultimately forms a networked hierarchical spatial structure.

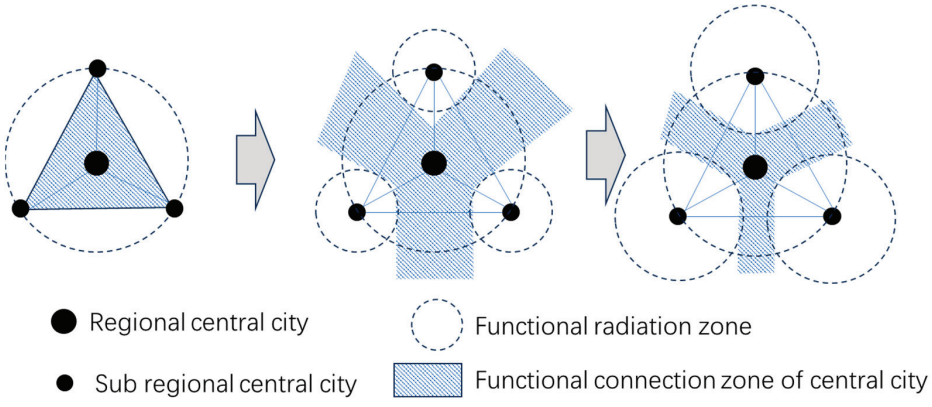


Figure 7. The evolution relationship of functional radiation ranges between central and sub-central cities in urban agglomerations.

4.4. The Well-Developed Transportation Network Can Effectively Enhance the Connectivity of Elements between Cities within the Metropolitan Area

The level of health and libraries infrastructures reflects the configuration and service capacity of urban health and libraries infrastructure facilities, as well as the comprehensive impact on the population demand of surrounding cities. Scholars have used indicators such as the number of beds in health institutions and the collection of public libraries to calculate the first-place index of health and libraries infrastructure s in Jiaxing City [37], whereas others have studied the first-place index of health and libraries infrastructure s in Zhengzhou City [54] using the medical service and social security indices. The measurement results are consistent with the actual development-level ranking of the region. It is suggested that further strengthening the regional transportation network can help improve the accessibility of basic health and libraries infrastructure resources within the metropolitan area, enhance the efficiency of the flow of health and libraries infrastructure elements between core and surrounding cities within the metropolitan area, and promote the integration of basic public services and social security.

The daily number of high-speed rail trips, intercity bus trips, and intercity subway connectivity reflects the degree of closeness between the city and the outside world. The external transportation factor connectivity index of Nanjing City is at a regional average level, with a range of 3.1 to 3.6, showing a fluctuating downward trend. As a port city along the Yangtze River and a regional transportation hub, Nanjing should strengthen its transportation infrastructure and continuously enhance its ability to provide external transportation services. Nanjing's urban opening-up indicators are constantly weakening, and it is necessary to leverage regional transportation networks to expand cooperation and connections between Nanjing and surrounding cities. Moreover, improvement of indicators such as foreign investment volume, actual scale of foreign investment use, total import and export volume, and tourism foreign exchange income through regional transportation networks should be developed. Previous studies conducted research analyses from the above four aspects and obtained conclusions consistent with the results of this study, confirming the correlation between the indicators and the rationality of the results [52].

We further explored the specific factors that led to the emergence of this trend. Various cities within the Nanjing metropolitan area are continuously strengthening industrial cooperation and emphasising the coordinated promotion of strong and complementary industrial chains. The industrial structure of the metropolitan area has been adjusted from 5.2:44.8:50.0 in 2016 to 4.3:43.6:52.1 in 2021, showing the characteristics of industrial and service industries jointly driving regional development. Especially since 2016, the construction of the transportation network in the Nanjing metropolitan area has accelerated,

resulting in a denser regional transportation network and more optimised transportation modes. The "1 h transportation circle" within the metropolitan area has been basically formed, and Nanjing has achieved closer transportation connections with surrounding cities. The gradual optimisation and improvement of industrial structure and transportation infrastructure have further enhanced the overall development level of surrounding cities near Nanjing.

The specific measures to improve the overall competitiveness of the Nanjing metropolitan area include the following aspects: firstly, accelerating the construction of a rail transit system, creating a "one-day living circle" and a "one hour commuting circle" in the metropolitan area, optimising the railway trunk network, promoting the construction of intercity railways and suburban railways, and forming a "meter" shaped high-speed railway network centred on Nanjing. Secondly, the region will jointly build a modern industrial system, focusing on manufacturing industry landmarks such as new energy vehicles, new displays, smart grids, and biomedicine and promoting the high-end and branded development of traditional industries. In addition, we will strengthen the radiation spillover effect of Nanjing as a globally influential innovative city and create an open and cooperative urban innovation system. Finally, promote regional collaboration in the fields of healthcare, education, culture, and tourism and build an integrated basic public service system.

5. Conclusions

5.1. Key Findings

This study aims at regional collaborative development and constructs a comprehensive evaluation index system for the primacy of central cities from the perspective of regional factor flow space, quantitatively measuring the level of intercity factor connections. This study breaks through the existing administrative division governance pattern of urban agglomerations, combines the evaluation of urban primacy with the optimisation of the urban agglomeration structure, proposes a regional collaborative governance model supported by elements such as economic connections, resource sharing, and project co-construction, as well as corresponding regional development strategies. This study used factor flow and geographic spatial regression analyses to quantitatively measure and spatially map the primary indicators of urban sub-items and obtained the following results:

(1) Nanjing has long ranked first in the comprehensive ranking; however, its score has shown a fluctuating downward trend, dropping from 0.956 in 2017 to 0.937 in 2023. The results indicate that the comprehensive level of Nanjing, as the central city of the metropolitan area, is constantly weakening, and its functional driving effect on the peripheral areas is also significantly weakened.

(2) The comprehensive urban primacy index spatial structure of cities within the metropolitan area presents a network hierarchical development feature of "one core, multiple centres, and multiple areas". The regional urban system structure is gradually taking shape, with Nanjing as the regional core city; Chuzhou (0.879), Yangzhou (0.915), and Wuhu (0.897) as sub-central cities; and other cities as sub-regional functional nodes.

(3) From the perspective of the urban sub-item primacy score, the indicators of economic (0.166 **), cultural (0.226 **), and transportation element connection (0.644 ***) are interrelated and mutually reinforcing, forming a unified entity with internal connections, thus jointly promoting the improvement of urban comprehensive primacy.

5.2. Implications

With the continuous advancement of regional integration, relationships between cities have shifted from traditional hierarchical structures to emerging spatial networks. Multicore and networked regional spatial structures have become a development trend in future regional urbanisation. Supported by the stream space theory and big data, there have been many in-depth studies on the spatial structure of regional networks; however, there is relatively little research on the spatial scope of regions based on the network space structure. Research has been conducted on the spatial scope of urban agglomerations based on an

analysis of network spatial structures, mainly using spatial and social network analysis methods [55]. The former mainly conducts network feature analysis from the perspective of physical transportation networks [42], whereas the latter studies the "spatial structure relationship" between cities [41], evaluating the level of urban systems through the strength of element connections between different cities [52].

Overall, there is relatively little research on this paradigm, partly because the flow data of empirical network analysis are often difficult to obtain [49], and partly because the influence between cities under the network correlation structure can have cross effects. The multiple interactions and superposition of influences between cities weaken the constraints of administrative boundaries in space. This study is based on an analysis of the evolution process, mechanism, and effects of the spatial connection pattern between the core and edge areas of urban agglomerations. Further, it explores the evolution mechanism of this type of heterogeneous spatial unit. This is an extension and expansion of the theory of regional spatial interactions and core edges and, thus, a beneficial innovative exploration. This study uses the flow space analysis and geographic spatial regression models, as well as various research techniques and methods, such as geography and spatial economics, to comprehensively analyse the effect mechanism of the interaction of various urban elements. The "flow space" big data is combined with traditional mathematical models to comprehensively measure the strength of spatial economic connections, with a certain degree of integrated innovation.

5.3. Limitations and Future Research Directions

The indicator system constructed in this study may have subjective expert biases, and the indicator weights determined using the subjective entropy weight method may be limited by the limitations of the research sample. Due to the limited availability of data, the city primacy evaluation index system set in this study needs to be improved. In future research, we will improve the evaluation index system for comprehensive primacy of the Nanjing metropolitan area. Specific index content can be further improved, and quantitative methods can be used to measure sub-item primacy in the future to enhance the reasonability of the research results. In addition, this study did not clearly distinguish between similar concepts, such as the primacy index and effect. In the future, relevant theories, such as comprehensive urban competitiveness and regional integration, should be combined to systematically construct a conceptual system for the comprehensive primacy of urban agglomerations on a regional scale.

Existing studies generally use linear interpolation as a substitute for data that has not been obtained in practice, which weakens the authenticity of the data to a certain extent. In future research, accurate first-hand data can be obtained by requesting government data disclosure or other means. Meanwhile, in the next step of the research, we can incorporate vector data, such as housing prices and population density distribution, to conduct spatial analysis, rather than simply using macro statistical data for rough regression. In future research, we will expand the timescale and refine the indicator-scale range.

We further compared and analysed the development models and paths of different types of urban fringe areas to obtain more realistic spatial distribution patterns and provide a more accurate reference for the formulation of spatial optimisation development policies. The next research focus will be on further enriching the indicator system of urban agglomerations and exploring more reasonable research methods. We will focus on building an integrated innovative development mechanism that breaks the traditional administrative governance model. We will take urban agglomerations as the starting point, strengthen the connection of spatial elements, and achieve coordinated development of the regional economy.

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References

1. Eklund, M.D.; Kowal, P.J.; Dupont, M.N. Evaluation of temperature-dependent critical experiments at the walthousen reactor critical facility for benchmark development. *Ann. Nucl. Energy* **2023**, *180*, 109440. [CrossRef]
2. Jefferson, M. Why geography? The law of the primate city. *Geogr. Rev.* **1989**, *79*, 226–232. [CrossRef]
3. Marshall, J. *The Structure of Urban Systems*; Toronto University of Toronto Press: Toronto, ON, Canada, 1989; Volume 3, pp. 17–32.
4. Yang, Q.; Wang, J.; Liu, X. MAS-Based Interaction Simulation within Asymmetric Information on Emergency Management of Urban Rainstorm Disaster. *Complexity* **2020**, *2*, 1–13. [CrossRef]
5. Campos, A.; Murillo, J.H.; Rodriguez, S. Temporal and Spatial variations in Organic and Elemental carbon concentrations in PM10/PM2.5 in the Metropolitan Area of Costa Rica, Central America. *Atmos. Pollut. Res.* **2013**, *4*, 53–63. [CrossRef]
6. Karnecki, K.; Wroclawski, A.; Dalewski, W.G. Homicide numbers, rates, and victims' characteristics in the tri-city metropolitan area, poland, between 2010 and 2019. *Arch. Med. Sadowej I Kryminol.* **2024**, *73*, 285–293. [CrossRef]
7. Dyer, L.; Jé, J.; Jahn, J.L.; Wallace, M. Investigating the black birth experience: A race-stratified analysis of preterm birth risk and exposure to metropolitan statistical area-level police-related deaths, us 2018–2019. *J. Urban Health* **2024**, *101*, 464–472. [CrossRef] [PubMed]
8. Pham, S. Places left behind? declining inner suburbs in the toronto census metropolitan area, 1980–2015. *Cities* **2024**, *146*, 111–117. [CrossRef]
9. Ramond, Q. The politics of social mix in the paris metropolitan area. *Hous. Stud.* **2024**, *39*, 419–437. [CrossRef]
10. Mehdipanah, R.; Mcvay, K.R.; Schulz, A. Historic redlining practices and contemporary determinants of health in the detroit metropolitan area. *Am. J. Public Health* **2023**, *113*, S49–S57. [CrossRef]
11. Lepoutre, T.J. Diffusion indexes of state and metropolitan area employment changes. *Mon. Labor Rev.* **2022**, *1*, 1–13. [CrossRef]
12. Cornet, D.; Bonnet, J.; Sébastien, B. Correction to: Digital entrepreneurship indicator (dei): An analysis of the case of the greater paris metropolitan area. *Ann. Reg. Sci.* **2022**, *71*, 725. [CrossRef]
13. Meng, M.; Yang, Y.; Shang, Y. Did highways cause the urban polycentric spatial structure in the shanghai metropolitan area? *J. Transp. Geogr.* **2021**, *92*, 103022. [CrossRef]
14. Uchino, T.; Kotsuji, Y.; Kitano, T.; Shiozawa, T. An integrated youth mental health service in a densely populated metropolitan area in japan: Clinical case management bridges the gap between mental health and illness services. *Early Interv. Psychiatry* **2022**, *16*, 568–575. [CrossRef]
15. Maragno, D.; Dall'Omo, C.F.; Pozzer, G.; Musco, F. Multi-risk climate mapping for the adaptation of the venice metropolitan area. *Sustainability* **2021**, *13*, 1334. [CrossRef]
16. Szabzon, F.; Perelman, J.; Sónia, D. Challenges for psychosocial rehabilitation services in the lisbon metropolitan area: A qualitative approach. *Health Soc. Care Community* **2019**, *27*, 4–16. [CrossRef]
17. Pribadi, D.O.; Vollmer, D.; Pauleit, S. Impact of peri-urban agriculture on runoff and soil erosion in the rapidly developing metropolitan area of jakarta, indonesia. *Reg. Environ. Chang.* **2018**, *18*, 2129–2143. [CrossRef]
18. Ruci, W.; Ahmed, D.; Yuji, M. Spatiotemporal simulation of future land use/cover change scenarios in the tokyo metropolitan area. *Sustainability* **2018**, *10*, 2056. [CrossRef]
19. Melo, P.C.; Graham, D.J.; Levinson, D. Agglomeration, accessibility and productivity: Evidence for large metropolitan areas in the US. *Urban Studies.* **2017**, *54*, 179–195. [CrossRef]
20. Zhou, J.; Xu, J.; Wang, X. Spatial agglomeration and performance of main innovative actors in a metropolitan area: Case study of the Yangtze River Delta metropolitan area. *Int. Reg. Sci. Rev.* **2018**, *41*, 630–656. [CrossRef]
21. Santana, D.; Barros, E.G.; Costa, R.; Veiga, G.V. Temporal changes in the prevalence of disordered eating behaviors among adolescents living in the metropolitan area of rio de janeiro, brazil. *Psychiatry Res.* **2017**, *253*, 64–70. [CrossRef]

22. Paredes, J.P.; Gutierrez, A.J.; Xiberta, J. Wood Residue to Energy from Forests in the Central Metropolitan Area of Asturias (NW Spain). *Urban For. Urban Green.* **2015**, *14*, 195–199. [CrossRef]
23. Obregón, S.A. Choice of transport in urban and periurban zones in metropolitan area. *J. Transp. Geogr.* **2022**, *100*, 101–113.
24. Choi, S.; Chae, J.; Do, M. Emergency road network determination for seoul metropolitan area. *Sustainability* **2022**, *14*, 5422. [CrossRef]
25. Pratama, A.P.; Yudhistira, M.H.; Koomen, E. Highway expansion and urban sprawl in the jakarta metropolitan area. *Land Use Policy* **2022**. [CrossRef]
26. Carleton, L.; Joyeux, R.; Milunovich, G. Rail stations and residential sorting: The case of sydney metropolitan area. *Urban Stud.* **2022**, *59*, 81–99. [CrossRef]
27. Mcdonald, J.F. The changing relationship between metropolitan area population growth and central city decline in the us manufacturing belt. *Ann. Reg. Sci.* **2022**, *71*, 299–316. [CrossRef]
28. Liu, K.; Murayama, Y.; Ichinose, T. A multi-view of the daily urban rhythms of human mobility in the tokyo metropolitan area. *J. Transp. Geogr.* **2022**, *91*, 102–112. [CrossRef]
29. Salavisa, I.; Maria, F.; Bizarro, S. The transition of the agro-food system: Lessons from organic farming in the lisbon metropolitan area. *Sustainability* **2021**, *17*, 9495. [CrossRef]
30. Kongphunphin, C.; Srivanit, M. A multi-dimensional clustering applied to classify the typology of urban public parks in bangkok metropolitan area, thailand. *Sustainability* **2021**, *13*, 11426. [CrossRef]
31. Chen, W.; Wang, G.; Zeng, J. Impact of urbanization on ecosystem health in Chinese urban agglomerations. *Environ. Impact Assess. Rev.* **2023**, *98*, 106964. [CrossRef]
32. Zhu, S.; Zhou, Z.; Li, R. Impact of High-Speed Rail Construction on the Environmental Sustainability of China's Three Major Urban Agglomerations. *Sustainability* **2022**, *14*, 2567. [CrossRef]
33. Feng, R.; Wang, K. The direct and lag effects of administrative division adjustment on urban expansion patterns in Chinese mega-urban agglomerations. *Land Use Policy* **2022**, *7*, 112–120. [CrossRef]
34. Wang, L.; Hu, H.; Wang, X. The Dynamic Evolution of the Structure of an Urban Housing Investment Niche Network and Its Underlying Mechanisms: A Case Study of 35 Large and Medium-Sized Cities in China. *Sustainability* **2022**, *14*, 3523. [CrossRef]
35. Zheng, W.; Du, N.; Wang, X. Understanding the City-transport System of Urban Agglomeration through Improved Space Syntax Analysis. *Int. Reg. Sci. Rev.* **2022**, *45*, 161–187. [CrossRef]
36. Xia, H. Delineating early warning zones in rapidly growing metropolitan areas by integrating a multiscale urban growth model with biogeography-based optimization. *Land Use Policy* **2020**, *90*, 18–33. [CrossRef]
37. Phelps, N.A.; Wijaya, H.B. Growth and growth constraints in craft industry clusters: The batik industries of Central Java. *Singap. J. Trop. Geogr.* **2020**, *41*, 7–19. [CrossRef]
38. Can, Z.; Gang, Z.; Ze, M. Monocentric or polycentric? A study of technological knowledge in five major urban agglomerations of China. *Geogr. Res.* **2019**, *38*, 235–246.
39. Pan, J.; Lai, J. Spatial pattern of population mobility among cities in China: Case study of the National Day plus Mid-Autumn Festival based on Tencent migration data. *Cities* **2019**, *94*, 55–69. [CrossRef]
40. Gornig, M.; Goebel, J. Deindustrialisation and the polarisation of household incomes: The example of urban agglomerations in Germany. *Urban Stud.* **2018**, *55*, 790–806. [CrossRef]
41. Cao, S.; Hu, D.; Zhao, W. Monitoring Spatial Patterns and Changes of Ecology, Production, and Living Land in Chinese Urban Agglomerations: 35 Years after Reform and Opening Up, Where, How and Why? *Sustainability* **2017**, *9*, 766. [CrossRef]
42. Maly, J.; Mulí, O. European territorial cohesion policies: Parallels to socialist central planning? *Morav. Geogr. Rep.* **2016**, *24*, 14–26. [CrossRef]
43. Juliano, E.; Malheiros, T.F.; Marques, R. The involvement of community leaders in healthcare, the environment and sanitation in áreas of social vulnerability. *Ciência Saúde Coletiva* **2016**, *21*, 789–796. [CrossRef] [PubMed]
44. Storper, M.; Christopherson, S. Flexible Specialization and Regional Industrial Agglomerations: The Case of the U.S. Motion Picture Industry. *Ann. Assoc. Am. Geogr.* **2015**, *77*, 104–117. [CrossRef]
45. Furjan, M.; Tomicic, K. Understanding Digital Transformation Initiatives: Case Studies Analysis. *Bus. Syst. Res. J.* **2020**, *11*, 125–141. [CrossRef]
46. Teece, D.; Leih, S. Uncertainty, innovation, and dynamic capabilities: An introduction. *Calif. Manag. Entreview* **2016**, *58*, 5–12. [CrossRef]
47. Schot, J.; Steinmueller, W.E. Three frames for innovation policy: R&D, systems of innovation and transformative change. *Res. Policy* **2018**, *47*, 1554–1567.
48. Luo, S.; Zhen, F.; Zhang, S. A conceptual model and methodological framework for examining urban people flow space based on complex network perspective. *Geogr. Res.* **2021**, *40*, 1195–1208.
49. Burger, M.; Goei, B.; Van, L.; Huisman, F.J. Heterogeneous development of metropolitan spatial structure: Evidence from commuting patterns in English and Welsh city-regions, 1981–2001. *Cities* **2011**, *28*, 160–170. [CrossRef]
50. Yishuai, Z.; Min, Z.; Qixuan, W.; Yao, C. Research on the Development of "Greater Bay Area" from the Dual Perspectives of "Space of Places" and "Space of Flows": A Case Study of Guangdong-Hong Kong-Macao Greater Bay Area. *China City Plan. Rev.* **2020**, *29*, 35–45.

51. Yishuai, Z.; Min, Z.; Yao, C. Identification and classification of urban clusters in China: The perspectives of network connections and local attributes. *Urban Plan. Forum* **2020**, *4*, 18–27.
52. Zhi, Y.; Li, H.; Wang, D.; Liu, Y. Latent spatio-temporal activity structures: A new approach to inferring intra-urban functional regions via social media check-in data. *Geo-Spat. Inf. Sci.* **2016**, *19*, 94–105. [CrossRef]
53. Zhang, Y.; Gu, Z.; Zhou, W. Spatial match of jobs-housing and the rail transit's role in commuting metropolis: A case study of Shenzhen. *Urban Plan. Forum* **2018**, *1*, 99–106.
54. Guo, L.; Bi, Y.; Huang, J.; Zheng, C.; Hu, G.; Wang, G. Multi-scale Comparison and Analysis of Jobs-housing Spatiale Characteristics in Big Cities—Taking Wuhan as an Example. *Urban Plan* **2018**, *5*, 88–97.
55. De, W.; Xiyuan, R. Distribution and composition of actual population in urban space from daily human mobility view. *Urban Plan. Forum* **2019**, *2*, 36–43.

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Research on the Socio-Spatial Resilience Evaluation and Evolution of the Central Area of Beijing in Transitional China

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Abstract: In recent decades, the increasing threats of global climate change, natural disasters, and epidemics have brought extensive attention to resilience theory. However, most studies focus on the physical aspects of cities, overlooking the significance of the social perspective. This study addresses this gap by using social areas as the core spatial unit for analysis. By constructing a scientific indicator system and employing the set pair analysis method, this study comprehensively evaluates the multidimensional resilience levels of Beijing's central area during its transitional period (1990–2020). The findings reveal that socio-spatial divisions, which emphasize the network structure of social relations and the dynamic changes in social spaces, are more suitable than traditional administrative divisions as fundamental units for resilience assessment. During Beijing's transitional period, the comprehensive resilience of the central area and all social areas steadily increased, although social capital resilience faced the challenges of loss and slow recovery. Social areas with a unique internal connection, such as those based on ethnicity, exhibited more positive social capital resilience development. Additionally, social areas with lower population diversity and greater homogeneity tended to have higher comprehensive resilience and a more positive trend in social capital resilience development, whereas highly heterogeneous social areas faced significant constraints in resilience development. These findings may provide valuable insights for cities and communities to enhance their capacity to address future uncertainties and assist policymakers in making informed governance decisions.

Keywords: social space; resilience; transition; Beijing city

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1. Introduction

Although it has a history of over 100 years, resilience theory has experienced a burgeoning currency in the past two or three decades, in parallel with global climate change and ensuing natural disasters, as well as epidemic disease, fluctuating financial markets, and a global escalation in terrorist attacks. What was rooted in psychology as an enquiry into individual persistence now converges with explorations into ecosystem dynamics and has grown into a broad and exciting field of study, gaining increasing popularity among academics, and capturing the interest of both policymakers and the general public. Not only does resilience theory provide an increasingly vigorous and sophisticated body of analysis, it also offers the prospect of more integrated and effective policy making aimed at sustainability [1]. To some extent, 'resilience is to the 2000s and 2010s what sustainability was to the 1980s and 1990s' [2].

It would be natural to wonder why multiple independent threads of research with different subjects, methods, and terminology have coalesced around the broad theoretical structure of resilience [3]. The authors believe that the subjects in question have one thing in common: humanity. Tremendous attention has been paid to the risks facing humanity

and its inter-coupled social-ecological systems through the lens of resilience thinking. This is why resilience research is prevailing and thriving in so many disciplines and cross-fields. Resilient thinking concerns humanity, and the fundamental happiness and wellness of all human beings, individuals, families, communities, cities, nations, and the entire global population, regardless of whether it is in the fields of psychology, ecology, economics, emergency management, or disaster risk reduction. The other reason resilience is so vital is that change is normal and inevitable in both nature and human society. We always have to prepare for, respond to, and recover from hardships and adversity in order to survive and thrive, especially when we are facing a locally and globally fast-changing natural and social environment. Therefore, resilience may be a 'response to a generalized contemporary sense of uncertainty and insecurity and a search for formulas for adaptation and survival' [4].

Unsurprisingly, the concept of resilience and its research framework are rapidly gaining widespread recognition and application across various fields, particularly in the evolving environments of cities and communities. Globally, the number of people living in cities has recently increased to 57% [5]. A similar process is occurring in China. In 2023, the urbanization rate of China reached 66.16%, which means more than 700 million people are currently living in cities in China. Urban resilience is the ability of a city as a complex dynamic system to maintain and recover its original state in response to various risks, ensuring the normal functioning of its internal systems. As climate change and its resultant extreme weather events and induced natural disasters increasingly affect cities, many city governments are considering enhancing urban resilience as a key coping strategy. According to the existing literature, research into urban resilience primarily focuses on two main areas: ecological sciences and engineering. Research topics such as urban emergency management, disaster mitigation, and climate change adaptation dominate most emerging research agendas in resilience thinking. Some scholars have assessed the urban resilience of Beijing using mixed-methods research, expert consultation, and factor analysis, exploring the strong link between resilience and climate change adaptation [6]. Other scholars have comprehensively assessed the resilience level of the Beijing–Tianjin–Hebei region, analyzing the dynamic relationship between climate factors such as temperature, precipitation, and wind speed and urban resilience, subsequently proposing targeted improvement measures [7]. Research related to urban disaster risk focuses on cities' ability to adapt to natural disasters, with in-depth explorations of specific types of disasters, such as floods [8,9], earthquakes [10,11], and landslides [12]. As the application scope and theoretical connotation of resilience theory continue to expand, the perspective of urban resilience research has gradually shifted from the ecological, natural, and engineering fields to internal social problems within cities.

In general, resilience research rarely integrates social structure with physical space. This study posits that resilience should be redefined from the perspective of urban sociology, emphasizing the role of space in social dynamics. From a geographical perspective, the concept of resilience must be linked to the uneven development of capital across different spatial regions and scales [13]. One viewpoint suggests that resilient spaces align with the interests of capital, transforming themselves periodically to meet the demands of capital accumulation within the context of economic globalization. From this perspective, both resilience and external interferences are components of the capital system, with capitalist resilience necessitating specific regions and groups to bear the costs of cyclical adjustments and transformations [14]. An alternative perspective views resilience as a manifestation of different social relationships, where the health and integrity of the social and physical environment take precedence, and capital is seen as an external disturbance and deconstructive force. This perspective aligns with the principles of social justice. This paper supports the latter view, especially in transitional economies like China's socialist market economy, where the resilience of social space cannot be fully explained within the capital system. The so-called spatial resilience of capital is merely a terminological rebranding of capitalist space, leading to both spatial destruction and social deconstruction, rather than genuine socio-spatial resilience. To thoroughly analyze the essence of socio-

spatial resilience, it is essential to re-examine the connotations of social space. Social space is a construct that integrates material, spiritual, and social dimensions. It is a product of human activities, both shaped by and shaping these activities, grounded in the material environment and social relations. Simultaneously, it reproduces the material environment and social relations, embodying the materialization of social existence. Given the richness of social space, it naturally aligns with the concept of resilience. Resilience refers to the capacity to remain stable, adapt to change, and recover in the face of challenges or pressures. Due to its inherent diversity, dynamism, and complexity, social space has the potential to address various challenges and changes. Therefore, exploring the resilience of social space involves investigating how to maintain the stability and vitality of social space to achieve its sustainable and healthy development in an ever-changing social environment.

The whole of China has been experiencing a rapid process of urbanization over the last few decades following its 'opening-up' policy of 1978. New towns have been built almost overnight, while old ones have been rapidly torn down. Numerous projects to renew ancient inner-city areas have led to the loss of city culture and heritage, social segregation, housing and job spatial mismatch, traffic congestion, the degradation of the environment, soaring real estate prices, indifferent social relations, frequent corruption, and even collective community demonstrations and social rioting induced by forced population relocation. These problems have just begun to manifest themselves. The magnitude of their impact will last for a long time, and may leave multiple complex issues for future generations to solve. Lessons should be learned from the past; fresh angles or new mindsets, and more dynamic and holistic perspectives and insights, ought to be applied to comprehensively and systematically analyze these issues faced by inner cities and communities. Resilience thinking is one such theory and angle of approach. With its cross-disciplinary and systemic nature, it can provide us with the basis for improving the quality of life of inner-city residents and inner-city environmental sustainability.

Following the outbreak of COVID-19, the crucial value of resilience came to the fore in combating the pandemic and restoring the normal functioning of cities and communities, including the resumption of production. Numerous studies into resilience as seen from various perspectives have emerged. Some scholars have developed a dynamic resilience assessment framework to quantify the resilience of different cities during large-scale public health events. This framework thoroughly analyses urban resilience across various epidemic scenarios and policy contexts, providing decision-makers with a basis for balancing the control of public health events and the maintenance of normal city operations [15]. Additionally, some researchers constructed a comprehensive four-dimensional evaluation model to assess urban resilience in terms of physical structure, infrastructure, socio-economic status, and environmental factors. These researchers calculated the resilience levels of 351 communities in Tehran, Iran in the context of the COVID-19 pandemic [16]. By combining these resilience levels with confirmed case data, the close relationship between community resilience and the severity of the impact of the pandemic has been further elucidated. These studies have partially validated the definition and understanding of socio-spatial resilience as proposed in this study. However, related research remains deeply constrained by administrative divisions when selecting spatial scales, failing to fully capture the complex aspects of human social relations. This significantly constrains the depth of such research and its applicability to real-world scenarios. After the COVID-19 pandemic, a new round of economic stimulus policies allocated tens of trillions of dollars toward the renovation of old cities and communities in China. In this context, the internal socio-spatial structure of Chinese cities will undoubtedly undergo significant changes and evolution, with corresponding adjustments to their patterns of resilience.

Against this background, this study first categorized the types of social space in the central area of Beijing City. It then conducted a comprehensive resilience assessment of these social areas across multiple dimensions and time periods, spanning various administrative regions. This deep-dive approach aimed to understand the complexity and diversity of social spaces. By exploring the development paths of social areas and the dynamic trends

in their resilience in central Beijing, this study provides theoretical support and practical guidance for addressing black swan events, such as COVID-19, and other potential crises, thereby actively promoting the construction of resilient cities. The structure of the study is outlined as follows:

This study used socio-spatial division as its foundational spatial units. It conducted comprehensive resilience construction, assessment, and evolution analysis on each social area in central Beijing across eight dimensions—the economy, population, institutions, social capital, ecology, engineering, networks, and morphology—at multiple time points. First, Section 1 defines the concept of urban socio-spatial resilience by systematically comparing the connectivity between urban resilience and urban social space, as well as reviewing the progress in related research. Section 2 provides an overview of the study area, data sources, the construction of the indicator system, and the research framework, along with the specific implementation methods. Section 3 offers a detailed analysis of the multidimensional resilience dynamics in Beijing's central area as a whole, as well as within its individual social areas. In Section 4, the study further explores how the internal homogeneity and heterogeneity of social spaces contribute to resilience building. Additionally, this section discusses the research limitations and proposes directions for future studies. Finally, Section 5 presents the conclusions of this work.

2. Data and Methodology

2.1. Study Area

Beijing is located at longitudes 115.7°–117.4° E and latitudes 39.4°–41.6° N, encompassing an area of approximately 16,410.54 km^2. The study area selected for this paper is the central area of Beijing, as shown in Figure 1. Specifically, it includes the Dongcheng and Xicheng Districts, established following the 2010 adjustment of Beijing's administrative divisions, which consolidated the original Dongcheng, Chongwen, Xuanwu, and Xicheng Districts (See Figure 1). These districts form the central area for the protection of Beijing's historical and cultural heritage and the core functional area of the capital, as delineated in the *Beijing Main Functional Areas Plan*. This central area covers 32 blocks and an area of 92.39 km^2.

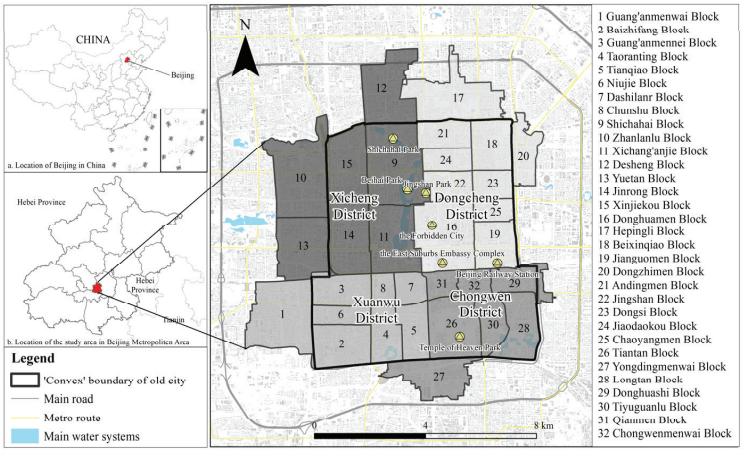


Figure 1. Location map of the study area.

Since 1978 and the introduction of reform and 'opening-up' policies, Beijing has experienced rapid development as China's capital, driven by its unique status and its international and historical value. The influx of elite talent and the rapid expansion of industries and economic markets have significantly contributed to the population growth in Beijing's central area, particularly since 1990. As a renowned historical and cultural city

and the political center of China, the development of Beijing's central area is of paramount importance to the Communist Party of China and the People's Republic of China for policy formulation and future planning. The central area faces a dual conflict between modern social development and the preservation of its historical and cultural heritage. Its historical legacy and associated socio-spatial changes pose obstacles for modern urban construction. The urban structure of this area of central Beijing has been of unique sociopolitical importance since the Ming and Qing dynasties, and has a rich history, diverse culture, and varied ethnic composition. As the heart of Beijing, it has undergone substantial change over different periods in response to economic development. The sustainable development of Beijing's central area is crucial for realizing the overall functions of the city, yet it faces numerous socio-spatial dilemmas. During the planned economy era, the central area had a 'decentralized group' spatial structure, characterized by a mix of old and new housing and generally poor construction standards. Following the introduction of reform and 'opening-up' policies, the functions and land structure of the area were reconstructed, bringing new socio-spatial problems, including housing issues for poor residents and the preservation of the old city's history and culture. Today, issues such as traffic congestion from daily commuting through old urban areas and related environmental problems remain pressing concerns. During public health crises like the SARS outbreak of 2003 and the COVID-19 pandemic, Beijing's central area faced considerable challenges in its response capabilities. This paper argues that the historical development and current realities of Beijing's central area offer a suitable paradigm for the socio-spatial resilience framework defined in this study. Consequently, this area is the scope of this study.

2.2. Data

The research period of this study spans from 1990 to 2020, aligning closely with a critical phase in China's economic and structural transition from centralized economy towards a more market-oriented one. Starting in 1990, Beijing initiated a large-scale renovation program for old city areas and concurrently promoted systematic reforms in the housing sector. By 2010, the housing stock and structure of Beijing's central areas had undergone accelerated reconstruction and social differentiation. The global outbreak of the COVID-19 pandemic in 2020 added complexity and variability to the context of this study. The pandemic has reshaped the global economy and profoundly impacted China's socioeconomic structures, including those of Beijing. Given Beijing's unique strategic position as the national capital, its diverse demographic composition, and the significant socio-economic changes it has experienced over the past three decades, this study focuses on an in-depth analysis of the central area of the city during the period from 1990 to 2020. Notably, the four years 1990, 2000, 2010 and 2020 correspond to national census years, providing valuable and detailed demographic data for this study. In terms of data collection and processing, the study additionally relies on the compilation of statistical data from these four key census years, including authoritative publications such as the *Beijing Social and Economic Statistical Yearbook* and the *Beijing Statistical Yearbook*. Additionally, the administrative divisions of the central area of Beijing underwent several adjustments during the study period. To ensure the spatiotemporal consistency of the data and accuracy of the results, data were merged and adjusted as necessary to accurately reflect the actual changes.

2.3. Methodology

The general research framework of this study is as follows: Initially, an index system for resilience assessment was developed, and the corresponding weights were calculated. Subsequently, set pair analysis was utilized to obtain the proximation of each dimension and year to the optimal set of evaluations in order to measure the corresponding level of resilience. Finally, the overall resilience value of the central area was summarized, and the resilience analysis of each dimension based on the results of the division into social areas was elaborated upon.

2.3.1. Construction of the Indicator System

Due to the inherent difficulties in measuring network resilience and morphological resilience with indicators, as well as the challenges of collecting early network-related data and maintaining the time series consistency of urban-morphology-related indicators, this paper selected only two indicators: the number of mobile phones per 10,000 households (to represent network resilience), and road network density (to represent morphological resilience). This selection of indicators adheres to the principles of scientific rigor, feasibility, and simplicity. Initially, alternative indicators were identified by synthesizing a substantial body of literature on resilience indicator systems to be included in the conceptual framework of socio-spatial resilience presented in this paper [17–37]. These indicators were grouped into two major categories: social and spatial resilience. These categories encompass the subcategories of economic resilience, demographic resilience, institutional resilience, social capital, ecological resilience, engineering resilience, network resilience, and morphological resilience, which can be collectively used to build an evaluation index system for urban socio-spatial resilience. The first four subcategories focus on the social level, while the last four focus on the spatial level.

After applying the principles of data continuity, reliability, accessibility, and the significance of the indicators, a total of 73 three-level resilience indicators were selected for this study. Specifically, the set includes 12 indicators of economic resilience, 12 of demographic resilience, 12 of institutional resilience, 12 of social capital, and 12 of ecological resilience. Additionally, there are 11 indicators of engineering resilience, along with a single indicator each for network resilience and morphological resilience. The entropy weight method was employed to assign weights and determine the final indicator system, as illustrated in Table A1.

2.3.2. Entropy Weight Method

The entropy value method is an objective weighting approach widely used in various assessment frameworks. It is applicable to a range of comprehensive evaluation problems and determines the weight of each indicator by calculating the degree of data dispersion, thus avoiding the potential influence of subjective judgment and human influence. Consequently, it more accurately reflects the true contribution of each indicator in the comprehensive evaluation system and helps improve the accuracy and reliability of the evaluated results.

In the evaluation index system for socio-spatial resilience in Beijing's central area, assuming there are n blocks, m years, and s indicators in the evaluation model, the jth indicator of block i in the ath year can be expressed as X_{aij}. In this paper, n, m, and s are 32, 4, and 73, respectively.

To eliminate scale differences between various indicators and ensure comparability of the processed data, this study employed the extreme value method. Indicators in the system are classified into two categories: positive indicators (where higher values are preferable) and negative indicators (where lower values are preferable).

Positive indicator:

$$X'_{aij} = \frac{X_{aij} - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}}. \quad (1)$$

Negative indicator:

$$X'_{aij} = \frac{\max\{X_j\} - X_{aij}}{\max\{X_j\} - \min\{X_j\}}, \quad (2)$$

where X'_{aij} is the standardized indicator value, X_j is the raw data of the jth indicator of block i in the ath year, and $\max\{X_j\}$ and $\min\{Xj\}$ are the maximum and minimum values of the raw data for the jth indicator over 4 years and 32 blocks.

To eliminate the impact of the extreme value '0' appearing in the logarithmic calculation process after standardization, this study shifted the standardized indicator value by 0.0001, thus:

$$X''_{aij} = X'_{aij} + 0.0001, \tag{3}$$

where X''_{aij} is the adjusted indicator value, and 0.0001 is the adjustment margin.

The index value after translation was transformed using the following formula:

$$P_{aij} = \frac{X''_{aij}}{\sum_{a=1}^{m}\sum_{i=1}^{n} X''_{aij}}, \tag{4}$$

where P_{aij} is the indicator weight of item j for block i in year a.

Finally, this study calculated the entropy value e_j of each index according to Formula (5) and calculated the entropy weight value W_j of the jth index using Formula (6), thus:

$$e_j = -\frac{1}{\ln(mn)}\sum_{a=1}^{m}\sum_{i=1}^{n} P_{aij}\ln\left(P_{aij}\right), \tag{5}$$

$$W_j = \frac{1-\mathrm{e}_j}{\sum_{j=1}^{s} 1-e_j}. \tag{6}$$

2.3.3. Set Pair Analysis

Set pair analysis (SPA) is a methodology that uses the number of connections to describe and manage certainty and uncertainty in complex systems [38]. This method subdivides certainty into 'identity' and 'discrepancy', and terms uncertainty as 'contrary'. It aims to explore the interaction between two interrelated sets in a dynamic system by analyzing the degree of connection among these three aspects. Since its introduction by Chinese scholar Keqin Zhao in 1989, the theoretical framework and practical approach of SPA have been widely applied in interdisciplinary fields, particularly in earth and environmental sciences [39].

Cities are complex and open systems, whose functioning and evolution are influenced by numerous deterministic and uncertain factors. Urban resilience refers to the capacity of a city to maintain stability and recover swiftly amidst uncertainty. Its essential characteristics closely align with those of complex systems, which are effectively addressed by SPA. Given that some scholars have already conducted studies using SPA to evaluate single or multiple subsystems within a city [40–42], the method has established a well-developed theoretical framework and methodological foundation in urban research. This study therefore aimed to quantify resilience using SPA in order to analyze the trajectory of change and gain a deeper insight into the internal operational mechanisms of the urban system. Using this method, it is possible to capture more accurately the performance of urban resilience across different dimensions, track its trends over time and space, and thus provide robust data support and a theoretical foundation for formulating scientific urban planning and management strategies. The details of the method are as follows:

The basic premise of SPA is that, given a specific problem context W, there exist sets M and N, denoted as set pair H. The expression for the connection degree μ is:

$$\begin{cases} \mu(W) = \frac{S}{N} + \frac{F}{N}i + \frac{P}{N}j = a + bi + cj \\ a + b + c = 1 \\ a, b, c \in [0, 1] \\ i \in [-1, 1] \\ j = -1 \end{cases}, \tag{7}$$

where N is the total number of elements possessed by the set pair H, while S, F, and P represent the number of identical properties, discrepant properties, and contrary properties of the two sets M and N. Without considering the weights, a, b, and c represent the degrees of 'identity', 'discrepancy', and 'contrariness' of the set pair H vis-à-vis the problem W being discussed. Here, i is the uncertainty coefficient, and j is the contrary coefficient.

In the specific multi-attribute evaluation problem $Q = \{F, D, E, W\}$ used to evaluate the socio-spatial resilience of Beijing's central area, $F = \{f_1, f_2, \ldots, f_m\}$ is the assessed year set, and f_m denotes the mth year.$D = \{d_1, d_2, \ldots, d_s\}$ is the evaluation indicator set, and d_s represents the sth index. $E = \{e_1, e_2, \ldots, e_n\}$ is the evaluation object set, and the e_n represents the nth block. $W = \{w_1, w_2, \ldots, w_s\}$ is the evaluation indicator weight set. By collecting the appropriate extreme value for each assessing index (the maximum for positive indicators and the minimum for negative indicators), the optimal evaluation set can be generated, marked as $U = \{u_1, u_2, \ldots, u_s\}$, while the pessimal evaluation set is marked as $V = \{v_1, v_2, \ldots, v_s\}$. u_s and v_s, respectively, express the optimal and pessimal value of the index d_s from 1990 to 2020. The connection degree of the set pair $\{f_m, U\}$ over $[V, U]$ is expressed as:

$$\begin{cases} \mu(f_m, U) = a_m + b_m i + c_m j \\ a_m = \sum w_{\mathrm{p}} a_{pk} \\ c_m = \sum w_p c_{pk} \end{cases} \qquad p = (1, 2, \ldots, s) k = (1, 2, \ldots, n), \tag{8}$$

where a_{pk} and c_{pk} represent the identity degree and contrary degree, respectively, of the evaluation index d_{pk} with the set $[v_p, u_p]$. Additionally, w_p denotes the weight of the pth index.

When d_{pk} has a positive impact on the evaluation result:

$$\begin{cases} a_{pk} = \frac{d_{pk}}{u_p + v_p} \\ c_{pk} = \frac{u_p v_p}{d_{pk}\left(u_p + v_p\right)} \end{cases}. \tag{9}$$

When d_{pk} has a negative impact on the evaluation result:

$$\begin{cases} a_{pk} = \frac{u_p v_p}{d_{pk}\left(u_p + v_p\right)} \\ c_{pk} = \frac{d_{pk}}{u_p + v_p} \end{cases}. \tag{10}$$

The approximate degree r_m of the subset f_m to the optimal evaluation set U can be defined as:

$$r_m = \frac{a_m}{a_m + c_m} \tag{11}$$

where r_m reflects the degree of connection between the evaluated subset f_m and the optimal evaluation set U. The larger the value of r_m, the closer the evaluated subset is to the optimal scheme. Using this method, the a_{pk} and c_{pk} values for the corresponding indicators of each block in the central area of Beijing from 1990 to 2020 could be obtained. By weighting these indicators, the a_{pk} and c_{pk} values for each block could be aggregated, using the block as the base unit, to calculate the a_m and c_m values for the entire central area or for each social area, before subsequently deriving the corresponding r_m values.

This study employed SPA to address the specific issue of socio-spatial resilience in the central area of Beijing. Multiple sets (different years within the same study area) were combined to provide a detailed analysis of resilience characteristics. The evaluation indices of socio-spatial resilience were synthesized into an approximate degree r_m in terms of the optimal evaluation set in order to reflect the resilience level. Here, a greater r_m value indicates a higher level of socio-spatial resilience, and vice versa.

3. Results and Analysis

3.1. Results of the Evaluation of the Comprehensive Resilience of the Central Area of Beijing

Taking the entire central area as the analytic unit, the performance of each resilience indicator in Beijing's central area gradually improved from 1990 to 2020 in terms of its approximation to the optimal evaluation set, indicating that the area's comprehensive resilience was on a steady upward trend. Specifically, the comprehensive resilience value increased from 0.3154 to 0.6703, demonstrating a consistent rise in resilience and improved risk resistance. Even though using only a single evaluative indicator for both the network and the morphological resilience may have affected the overall accuracy of the assessment, analysis after the exclusion of these two indicators still showed a consistent overall trend in the comprehensive resilience values. However, when the indicators were grouped into two dimensions, spatial and social, based on their nature, the central area showed some differences in how its resilience evolved. Spatial resilience grew significantly year on year due to infrastructure investment and road network optimization; social resilience exhibited fluctuations while trending upwards, with a short-term decline followed by a rapid rebound due to economic, demographic, and housing policy changes in 2000, reflecting the challenges and adaptations after the restructuring of the social fabric. By 2020, both dimensions had grown significantly, reflecting an overall increase in the city's comprehensive resilience, as shown in Table 1.

Table 1. Multi-perspective resilience of Beijing's central area.

Resilience Configuration	1990	2000	2010	2020
Comprehensive resilience	0.3154	0.3431	0.4628	0.6703
Comprehensive resilience (Excluding network and morphological dimensions)	0.3257	0.3491	0.4601	0.6567
Spatial resilience	0.2781	0.3478	0.4611	0.6927
Social resilience	0.3402	0.3399	0.4643	0.6544

Although the overall resilience of Beijing's central area grew during the study period, there were significant differences in performance across the various dimensions, as shown in Figure 2. Economic resilience climbed dramatically, with its value in 2020 reaching 6.7 times that of 1990. Population resilience grew slowly and consistently due to rising educational attainment, labor influx, and improved healthcare, but further growth was hindered by severe aging by 2020. Institutional resilience, although generally rising, slowed in 2000 due to economic transformation, increasingly complex demographic structures, and intensified demolition and relocation conflicts that occurred during the renovation of the old city. However, it showed significant growth with the optimization of housing policy, continuous legal improvements, and the development of the tertiary industry sector. By 2020, institutional resilience had achieved a significant breakthrough in its growth rate, fully demonstrating its high degree of adaptability and regulatory ability. The resilience of social capital was deeply affected by the renovation of the old city and the gentrification it brought about, resulting in significant fluctuations. From 1990 to 2000, socio-economic transformation, the renovation of the old city, and the commercialization of housing led to drastic changes in the area's social structure. The original community network in the central area was disrupted, causing a sharp decline in the resilience of social capital. By 2010, the restructuring of the urban and social structure created conditions for the reconstruction of social networks, leading to a brief rebound in social capital resilience, though it only slightly surpassed the 2000 level and failed to return to the 1990 benchmark. Between 2010 and 2020, the central area's economic structure transitioned from a balanced emphasis on manufacturing and services to an international, world-class economic system centered on high-end services. Meanwhile, the rise in China's internet and platform economies led to a diversification of employment patterns, with a significant increase in professionals working in emerging industries. Their reduced participation in traditional

social groups, such as trade unions, coupled with a significant reduction in the number of staff in other mass organizations, such as people's mediators, led to a significant decline in social capital resilience by 2020. Ecological and engineering resilience both showed a step-by-step stable growth, with ecological resilience rising even more due to increased greening, environmental management, and energy efficiency. This highlights the importance Beijing has placed on urban ecological and environmental protection over the past few decades, and the overall strength and success of its pollution prevention and control efforts. Network resilience stabilized after a significant increase in the popularity of smartphones and the mobile internet. Morphological resilience rose sharply after an initial decline, influenced to some extent by adjustments to the statistics caliber of road length, but also reflecting the continuous optimization of the road network in the central area and the compact nature of the urban road pattern.

The construction of resilient cities requires an integrated approach that combines the urban physical substrate with human society. However, urban resilience analysis is often conducted based upon administrative divisions and specific communities, with few studies using social areas as spatial units. Utilizing data from four population censuses, this study first divided the social space of Beijing's central area into eleven types of social areas: a relatively marginal population social area; an industrial worker social area; a Hui minority social area; a working-class social area; a high-density mixed-use social area; a middle-class social area; a middle-class and working-class mixed social area; an elite-class social area; a capital-class social area; a high-density scientific research talent social area; and a mixed immigrant social area. The relevant research methods, division criteria, and detailed processes are described in the earlier part of this research team's previous work [43]. Subsequently, this study used each social area as the basic spatial unit for resilience assessment to comprehensively and systematically evaluate the multidimensional comprehensive resilience level of Beijing's central area across the four census years.

As shown in Figure 2, a stable domestic and international socio-economic environment has promoted the rapid development of Chinese society. Along with the continuous strengthening of macro-policies, the comprehensive resilience of social areas in the central area has grown steadily. However, the internal variations in the resilience of social areas exhibit a dynamic change, first converging and then expanding. Specifically, in 1990, the middle-class social area was significantly ahead in terms of comprehensive resilience, while the Hui minority social area showed the lowest resilience. By 2000, the middle-class social area had maintained its advantage, while the working-class social area had experienced a decline in resilience to the lowest level. During this period, the disparities in comprehensive resilience narrowed but then tended to widen. By 2010, the middle-class social area had a narrow lead over the relatively marginal population social area, continuing to occupy the optimal position, while the high-density mixed social area became the social area with the lowest comprehensive resilience. By 2020, the Hui minority social area exhibited the highest comprehensive resilience, while the working-class social area again showed the lowest value. In summary, the middle-class social area and the relatively marginal population social area demonstrated higher comprehensive resilience over the long term. The former maintained a high level of comprehensive resilience due to its resource advantage and sensitivity to social change, while the latter relied on a stable living environment and community network to build strong social resilience. With the overall development of the central area and policy support, the Hui minority social area significantly increased its resilience, becoming the most resilient of all social areas by 2020.

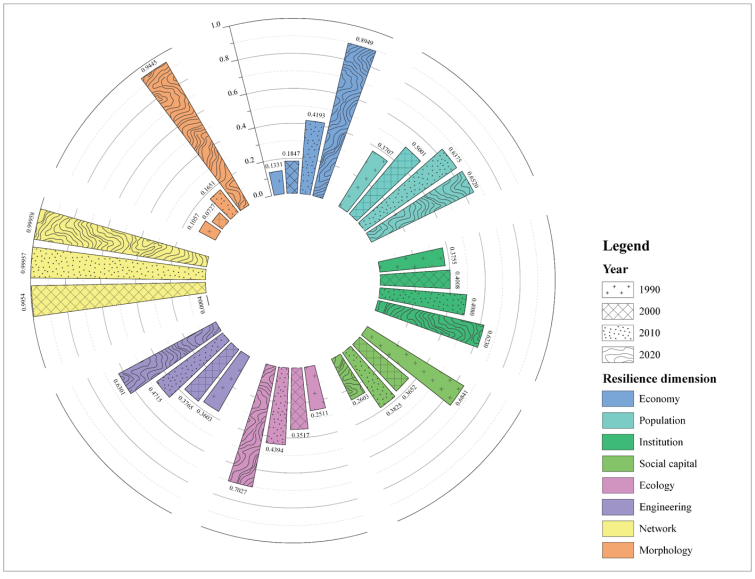
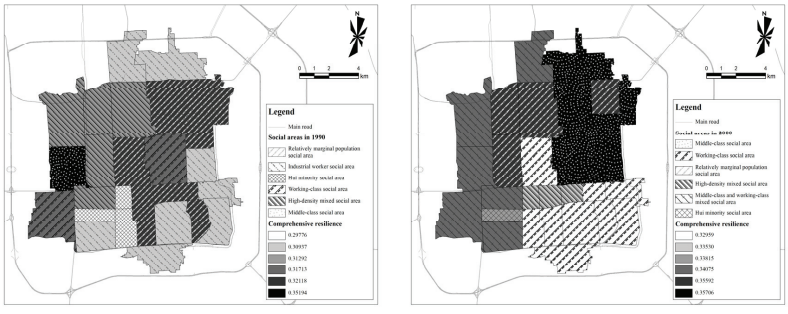


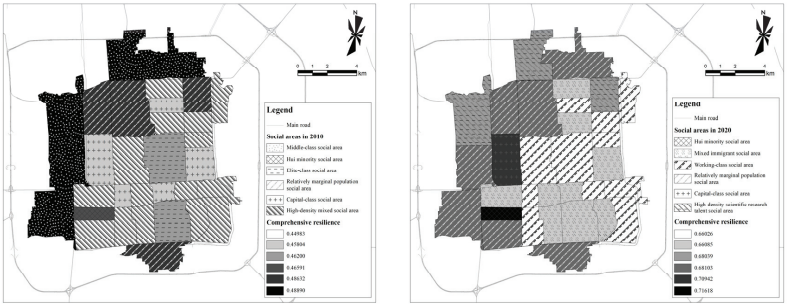
Figure 2. Multidimensional resilience of Beijing's central area, 1990–2020.

From the perspective of spatial distribution, the spatial location and scope of social areas have undergone significant change, but still maintain a certain degree of inheritance (See Figures 3 and 4). In 1990, high-resilience social areas were concentrated in the central area's mid-western parts, forming a compact layout; low-resilience social areas were mainly distributed on the area's northern and southern fringes. In 2000, some high-resilience social areas expanded to the periphery of the central area, while the former Chongwen District, known for its concentration of dilapidated housing, became home to the majority of low-resilience blocks. In 2010, some of the low-resilience social areas shifted inward into the central area, and the spatial distribution tended to be fragmented. By 2020, the scope of high-resilience social areas was expected to shrink significantly and become concentrated in the newly-formed Xicheng District. In contrast, the scope of low-resilience social areas expanded significantly into the central and eastern parts of the central area. This expansion may have been related to the regrouping of the working-class and migrant populations, which, due to limited resources and weak community ties, were drawn to the employment opportunities in these areas.



(**a**) (**b**)

Figure 3. *Cont*.



(**c**) (**d**)

Figure 3. Distribution and evolution of the comprehensive resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

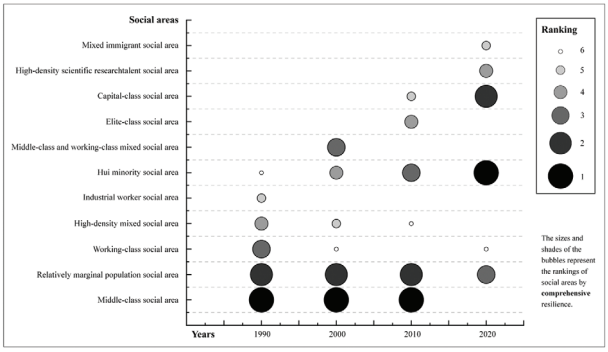


Figure 4. Bubble chart of the comprehensive resilience ranking changes across different social areas in Beijing's central area (1990–2020).

In analyzing the complicated process of urban socio-spatial resilience evolution, it is necessary to focus on the development of comprehensive resilience within social areas, and to interpret any changes in socio-spatial resilience within a complex urban system from many different dimensions. This study was based on two core dimensions, i.e., spatial and social, so that the research could be comprehensively conducted. The spatial perspective focused on the physical substrate of the city from the vantage point of four dimensions: its morphology, ecology, engineering, and network. The central area's social dimension was discussed from the perspective of another four dimensions: its economy, population, institutions, and social capital. Together, these eight dimensions constitute the basic structure and operating mechanisms of society and provide insight into the internal characteristics and risk response capacity of the central area of a mega-city.

3.2. Resilience Evaluation and Evolution Analysis from the Spatial Perspective

The development of morphological resilience has been somewhat uneven, with overall levels exhibiting an increase amidst fluctuations (See Figures 5 and 6). The primary reason for this may be adjustments to the statistics caliber of road length, which have affected the continuity of historical data and led to a significant decline in the morphological resilience value of some historical and cultural conservation areas. By 2010, the blocks where the Forbidden City and the Temple of Heaven are located had the lowest morphological resilience in the central area. However, by 2020, these areas showed significant resilience recovery and improvement, closely mirroring the overall enhancement of morphological resilience related to adjustments to the statistics caliber of road length. Meanwhile, historical and cultural conservation areas, due to their location in the city center, dense road networks,

and the benefits of effective maintenance and restoration strategies, rapidly recovered their morphological resilience. From the perspective of the overall evolution of morphological resilience rankings, the Hui minority social area and the middle-class social area demonstrated a consistent upward trend. In contrast, the high-density mixed social area initially experienced an increase but later saw a decline, while the area with relatively marginal populations underwent an initial decline followed by a subsequent rise. These trends reflect the differences in road network construction within the central areas. Despite these fluctuations, the overall level of morphological resilience made rapid progress between 2010 and 2020.

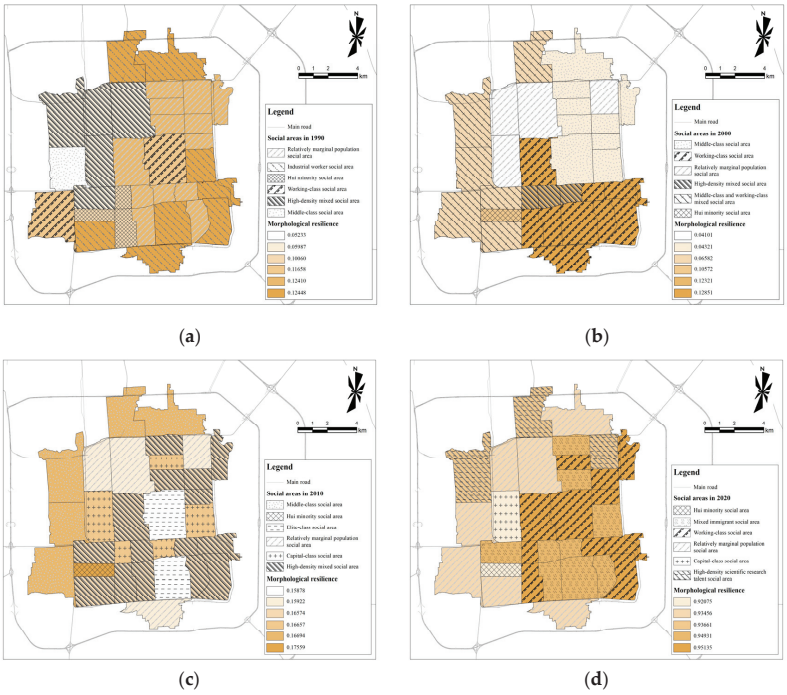


Figure 5. Distribution and evolution of the morphological resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

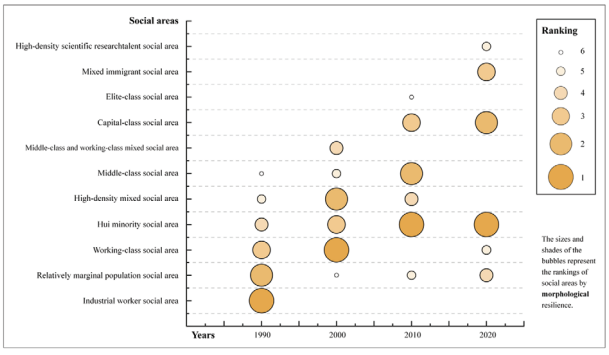


Figure 6. Bubble chart of the morphological resilience ranking changes across different social areas in Beijing's central area (1990–2020).

In terms of the development of ecological resilience in social areas, the relatively marginal population social area performed well, while the Hui minority social area experienced a shift from the lowest to the highest ecological resilience (See Figures 7 and 8). Significant differences in the developmental histories of these social areas' ecological resilience can be attributed to their geographic location and level of economic development. The relatively marginal population social area has a more stable settlement structure, located as it is on the northern side of the city's 'convex' structure; this area includes multiple historical and cultural conservation areas and ecological reserves such as Shichahai Park and Beihai Park. These areas have not undergone large-scale reconstruction, thus preserving their original ecological advantages. The Hui minority population is highly concentrated in the Niujie Block, a small area on the edge of Beijing's inner city that is predominantly composed of Hui residents. This population initially struggled with outdated environmental conditions and imperfect ecological management measures, making it difficult to improve ecological resilience. By 2020, ecological protection measures and development policies for minority residential areas began to take effect, leading to a significant improvement in ecological resilience. The middle-class population's ecological resilience gradually improved due to its pursuit of a high-quality living environment. In contrast, the high-density mixed social area consistently exhibited low levels of ecological resilience, as ecological conservation efforts have not been prioritized in this area.

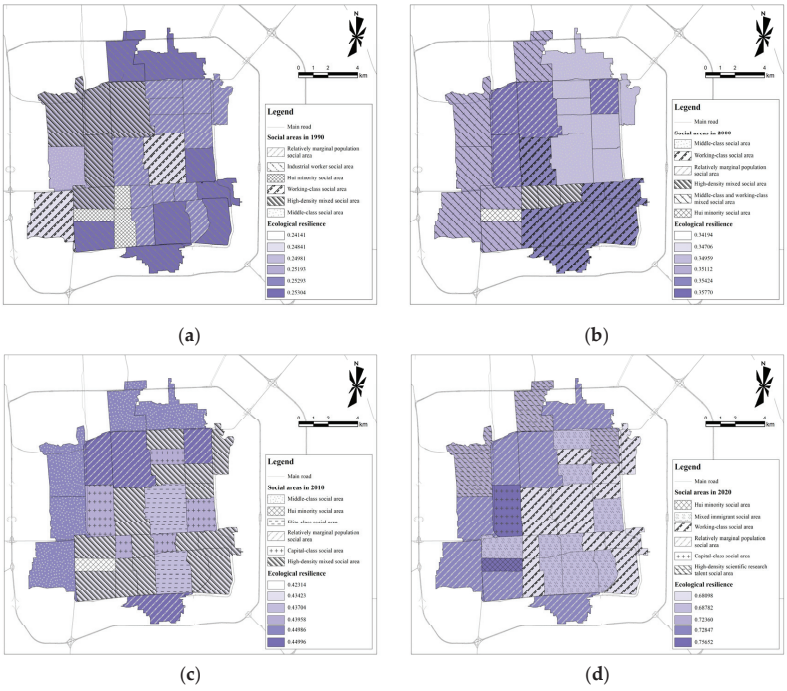


Figure 7. Distribution and evolution of the ecological resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

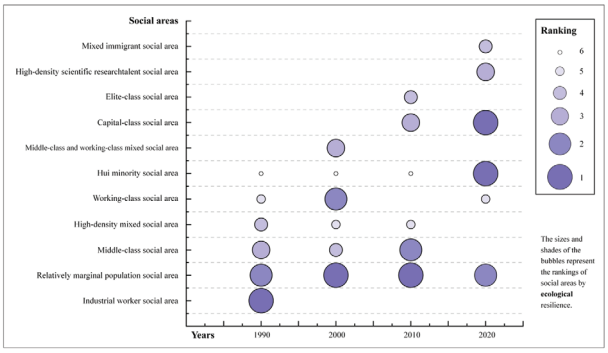


Figure 8. Bubble chart of the ecological resilience ranking changes across different social areas in Beijing's central area (1990–2020).

In the field of engineering resilience, the development of the relatively marginal population social area and the middle-class social area exhibited some similarities (See Figures 9 and 10), but there were significant differences in their underlying causes. From 1990 to 2010, the engineering resilience in both of the aforementioned social areas grew slowly during the first decade and then accelerated dramatically in the second decade, leading to considerable year-on-year variations in rankings. The relatively marginal population social area encompasses many traditional housing conservation blocks (e.g., Dashilanr, Jingshan), where restrictions on building height and floor area ratio were imposed during the area's renovation processes. Additionally, these areas contain a high density of dilapidated houses, which renders renovation projects unprofitable for developers and has led to delays in redevelopment efforts. Consequently, this has slowed the progress of resilience-building initiatives. Since 2000, the government's active efforts to balance the renovation of dilapidated buildings with heritage conservation and urban development have led to rapid improvements in infrastructure. As a result, the renovation projects in the old city have been progressively completed, leading to substantial increases in engineering resilience. By 2020, while the level of engineering resilience continued to rise, Beijing's rapid urbanization had reached an advanced and mature stage. This progression led to a significant slowdown in the rate of improvement in engineering resilience, as construction and renovation at the physical level approached saturation.

The development of engineering resilience in the middle-class social area can be intricately linked to changes in this population's location. In 2000, the inner city's middle-class social areas were situated in the former Dongcheng District, a key region earmarked for old city renovation. This area faced challenges such as balancing environmental protection and development, property disputes, and insufficient funds, which hindered renovation projects and delayed the construction of engineering resilience. Subsequently, as housing prices within the central area soared, the middle-class social area shifted back to the periphery of the central area. In these areas, where land available for development was more available and construction restrictions were less stringent, there was a significant improvement in engineering resilience. Furthermore, the engineering resilience of the Hui minority social area fluctuated significantly during the study period, showing rapid initial development followed by a slowdown and then a rebound. This fluctuation was primarily due to the unique characteristics of ethnic minority groups and historical factors. In 2000, due to the protection of religious buildings such as mosques and the preservation of ethnic customs, engineering renovation was limited. This resulted in a stable built environment and better engineering resilience in the Hui minority social areas compared to others undergoing significant transformation. However, as reconstruction efforts deepened, the constraints imposed by cultural conservation areas slowed down the upgrading of infrastructure and emergency facilities, gradually causing engineering resilience in these areas to lag behind that of other social areas that had completed substantial renovation.

By 2020, the Hui minority social area experienced significant improvements in public services and infrastructure. This was due to the explicit requirements of the 13th Five-Year Plan for strengthening infrastructure in ethnic minority areas, as well as the adoption and implementation of advanced technologies such as intelligent transportation systems and disaster risk reduction technology. These factors contributed to a notable enhancement in the engineering resilience of the Hui minority social area.

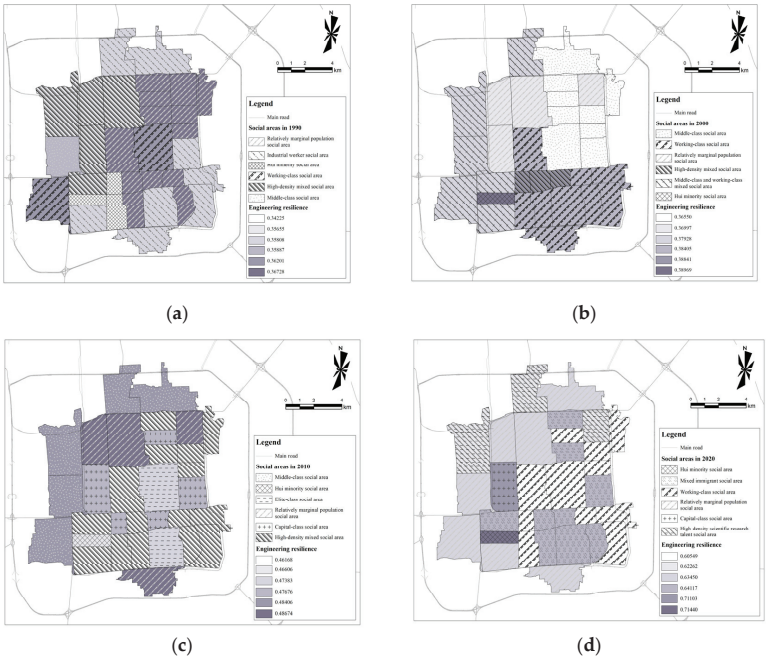


Figure 9. Distribution and evolution of the engineering resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

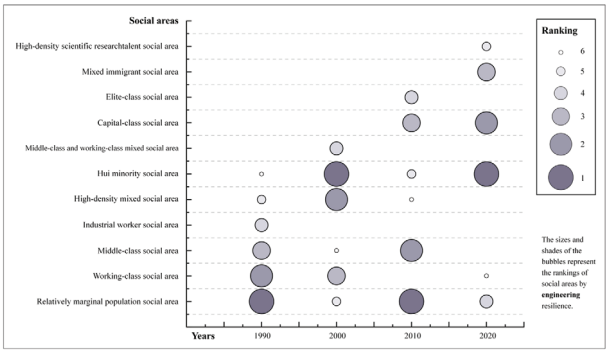


Figure 10. Bubble chart of the engineering resilience ranking changes across different social areas in Beijing's central area (1990–2020).

With the widespread adoption and rapid development of mobile internet technologies, the impact of network infrastructure on urban resilience is increasing. However, early challenges in data collection prevented the refinement of network resilience indicators at the block and social area levels, thus limiting the differential expression of this spatial dimension. From a temporal perspective, network resilience experienced a significant leap

between 1990 and 2020. Nonetheless, in the absence of major technological innovations and with the reliance on a single indicator, the development potential of network resilience became increasingly constrained between 2000 and 2020, resulting in a slowdown of its growth rate.

3.3. Resilience Evaluation and Evolution Analysis from the Social Perspective

Social resilience in Beijing's central area has undergone multilevel, differentiated development. Economic, demographic, and institutional resilience all exhibited positive and stable growth, except for social capital resilience, which fluctuated significantly. Since the implementation of reform and 'opening-up' policies and the establishment of the market economy system, diverse market entities have become the core driving force behind urban development. As the country's economic frontier, the central area of Beijing has experienced a significant enhancement in economic resilience, and the disparity in economic resilience between social areas has gradually diminished over time (See Figures 11 and 12).

Typically, marginalized populations are often viewed as groups with low literacy and low economic status. However, in central Beijing, social areas comprising such groups have demonstrated substantial economic resilience over an extended period. It is therefore important to clarify that the marginal populations discussed in this paper are not defined by absolute poverty. Instead, they primarily refer to a large group of non-local residents with relatively lower educational attainment who are somewhat marginalized within the central area. This social area is situated in a region with a strong economic base, where business has boomed since the 'opening-up' policies of the late 1970s. The tertiary sector has risen in importance, attracting a large number of migrants. The labor market in this area is characterized by high gender equality, and the economy is active and open. The advantages that come with the area's central location have provided relatively marginal populations with more opportunities to engage in diverse economic activities. As a result, these areas are predominantly inhabited by service industry workers, commercial migrant workers, and ethnic minorities, many of whom initially settled here to tap into economic opportunities as self-employed individuals. Over time, they have established stable and substantial sources of income, contributing to the overall high economic resilience of the area.

Between 1990 and 2010, the economic resilience of the central area's high-density mixed social area remained consistently low, though the growth rate accelerated in later years. Since the gradual transformation of China's housing system towards commercialization and marketization began, Beijing, as a pioneer city in these reforms, has piloted the sale of public housing, thereby enhancing residential mobility [44]. In 1990, this social area was mainly concentrated in the northwestern part of the central area, affected by housing policy reforms and an influx of migrant population. This resulted in a complex residential structure, large economic disparities, high unemployment rates, and weak economic resilience. By 2000, the high-density mixed social area had shifted to the Qianmen area, leveraging its traditional location advantages and historical industrial base, and thereby facilitating higher employment levels for residents and improved economic resilience. By 2010, the scope of the social area expanded and dispersed around Beijing's 'convex' old city. This expansion led to more diversified economic activities, a broader distribution of resources, increased economic vitality, and a significant improvement in economic resilience. By 2020, a new social area emerged in the central area characterized by a high density of people with scientific research talent. The high economic resilience of this area can be primarily attributed to the residents' high educational background, high income levels, concentrated employment in research-related positions, and strong job stability. These factors have collectively enhanced the area's economic resilience.

Located in the southwestern part of Beijing's central area, the Hui minority social area has long been affected by historical and social factors. The residents' educational attainment and economic status have been low, and commercial development has been limited, mainly meeting the basic needs of residents' lives, resulting in poor economic resilience. However,

with the improvement of the subway, bus, and other transport networks, the advancement of social mores, and the increase in population mobility, commercial development in this social area has accelerated significantly, gradually improving its economic resilience. Between 2010 and 2020, the Niujie Block attracted many domestic and foreign tourists due to its high visibility in overseas Islamic countries and the wide dissemination of its unique culinary culture on the internet. Commercial activities flourished, and economic vitality increased, making it a new economic growth engine, and significantly raising the level of economic resilience in the Hui minority social area.

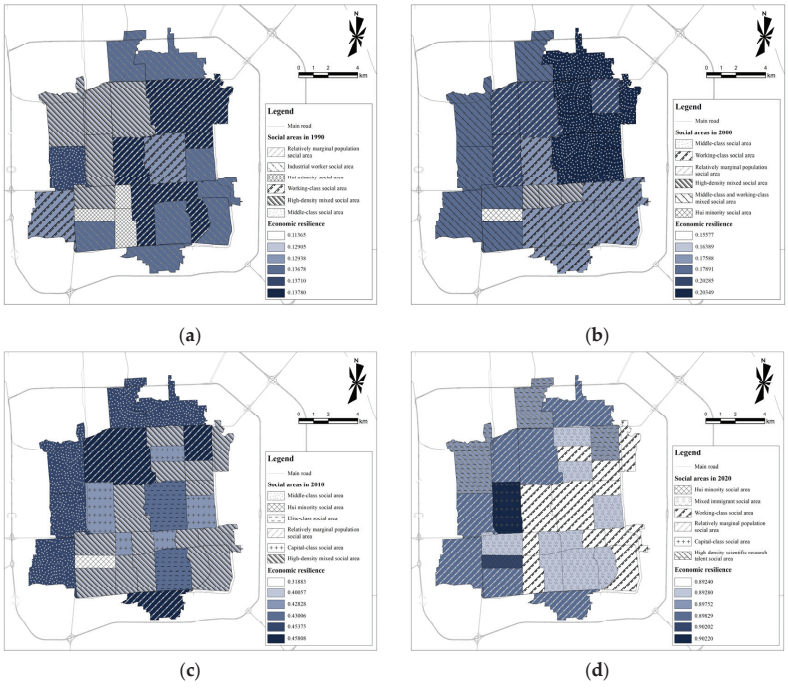


Figure 11. Distribution and evolution of the economic resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

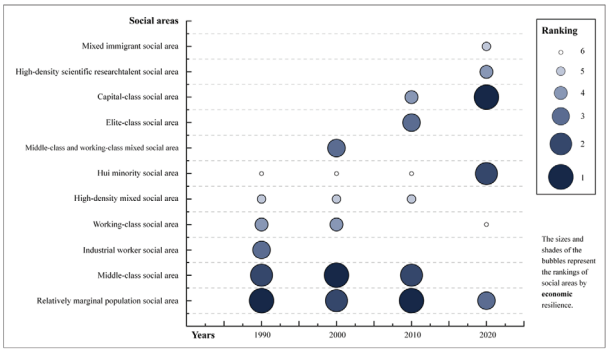


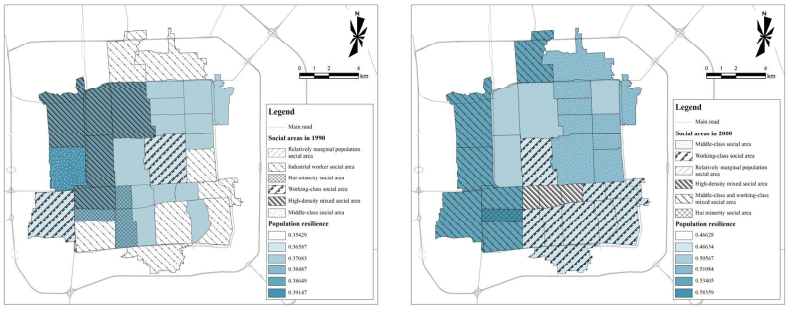
Figure 12. Bubble chart of the economic resilience ranking changes across different social areas in Beijing's central area (1990–2020).

Population resilience is a direct reflection of residents' ability to cope with multiple social, political, and environmental pressures, highlighting the importance of human

initiative. Within the central area, the middle-class social area has maintained a high level of population resilience over an extended period due to its young demographic structure, high gender equity, and high education level (See Figures 13 and 14). The Hui minority social area has consistently been in the upper middle range in terms of population resilience since 1990, due to its historical heritage and ethnic diversity. Within the context of the rapid development of modern cities, the elevated status of ethnic minorities, their increased access to education, the flourishing of new commercial opportunities, and increased population mobility have all led to a continuous improvement in the population resilience of the Hui minority social area. By 2020, while the population resilience ranking of the Hui minority social area remained relatively high, its absolute value had declined compared to 2010. This decline was due to multiple factors, including the worsening trend of aging and population outflow caused by industrial restructuring. These factors have affected the original Hui-dominated population structure and weakened its population resilience.

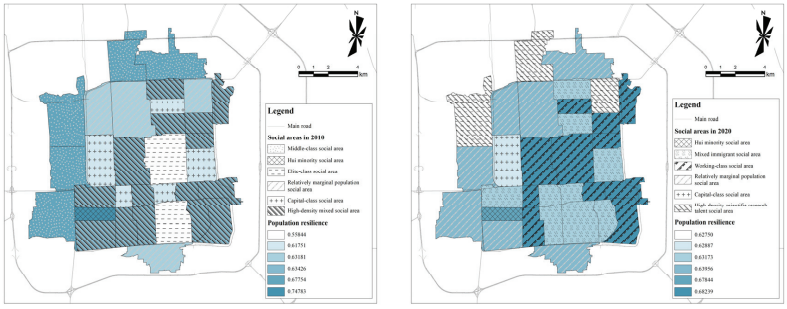
The 2010 social area classification clearly identifies regions inhabited by the capital and elite classes, often considered to be of high social status; however, these areas have exhibited deficiencies in population resilience. These areas are characterized by low population densities, small living spaces per capita, and limited ethnic diversity. The elite class is concentrated in the Donghuamen and Tiantan Blocks, which encompass extensive areas of land for public facilities due to their deep historical heritage and special social status, resulting in limited living spaces and consequently low population densities. The situation is similar for members of the capital class. They are also concentrated in blocks where residential land is scarce, such as the Jinrongjie Block, which is characterized by a high density of office buildings; Jianguomen, known for its cultural relics and transport hub functions; and Qianmen, a historical and cultural district predominantly used for commercial purposes. These factors have all contributed to relative lower population densities in these areas.

In 2020, the population resilience of the working-class social area significantly increased to the highest level in the central area. This phenomenon is mainly attributed to the optimal allocation of educational resources and significant economic growth, which led to a substantial increase in the average educational attainment of the working-class population. As society has developed, the sector of the working-class population with higher-than-average educational attainment has seen increased employment opportunities in the business sector, and women's occupational participation has gradually risen. Additionally, the large-scale renovation of the old city in the central area has effectively expanded the area's total living space, providing more spacious residential environments for the working class, thereby comprehensively improving their population resilience.



(**a**) (**b**)

Figure 13. *Cont.*



(**c**) (**d**)

Figure 13. Distribution and evolution of the population resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

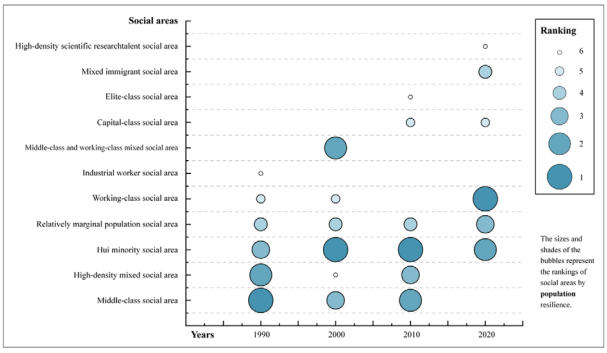


Figure 14. Bubble chart of the population resilience ranking changes across different social areas in Beijing's central area (1990–2020).

Institutional resilience reflects the ability of urban socio-spaces to withstand and adapt to multidimensional environmental changes. It is a critical component of urban socio-spatial resilience, showcasing the coordination and flexibility of macro-structures and their elements [45,46]. The middle-class social area has undergone a significant transformation in institutional resilience, shifting from weak to strong (See Figures 15 and 16). This trend of increased resilience has become more evident with population growth and areal expansion. In 1990, the Yuetan Block, which housed a concentration of middle-class residents, experienced political fragmentation, which impaired the block's administrative efficiency and weakened internal stability, resulting in a low level of institutional resilience. As Beijing's economy thrived, the middle class expanded rapidly. Between 1990 and 2010, its composition became more diverse, including highly educated individuals and other family groups with higher socio-economic status. Faced with institutional changes brought about by the city's rapid development, these groups adapted quickly and exhibited excellent coping strategies, becoming the core driving force behind the stable development of the area's institutional resilience.

The institutional resilience of the working-class social area has experienced a complex evolution throughout the study period, in parallel with its spatial changes. These areas are dominated by residents engaged in technical jobs and characterized by a certain level of education and professional skills. In 1990, these characteristics greatly facilitated the governance of the working-class social area and enabled the region to exhibit significant institutional resilience. However, the spatial extent of the working-class social area has changed considerably due to the renovation of the old city and its subsequent gentrification. In 2000, the working-class social area was concentrated in the relatively less redeveloped

former Chongwen District. By 2020, members of this social class had dispersed throughout the new Dongcheng District. Between 1990 and 2000, their institutional resilience value declined, dropping from the highest level in the central area to the lowest. By 2020, although the absolute value of institutional resilience of the working-class social area had increased, it remained at the lowest ranking within the central area. This decline was likely due to employment pressures from economic change, which complicated social governance, thus reducing institutional resilience.

From 1990 to 2010, the institutional resilience of both the high-density mixed social area and the Hui social area remained constantly low. The low institutional resilience of the high-density mixed social area was closely related to its complex demographic composition, lack of social security, and governmental challenges. In contrast, the Hui social area's institutional resilience ranking has decreased annually, primarily due to geographical limitations and relatively lagging overall levels of educational attainment. However, by 2020, the institutional resilience of the Hui social area saw a significant increase, reflecting the positive impact of improved education levels among ethnic minorities.

Between 2010 and 2020, the level of institutional resilience in the capital-class social area increased significantly, rising from a mid-level to the highest level in the central area. During this period, the spatial distribution of the capital-class social area gradually evolved from dispersed to concentrated. By 2020, these areas were primarily concentrated in the Jinrongjie Block, and their spatial concentration gave them prominence in all facets of institutional resilience.

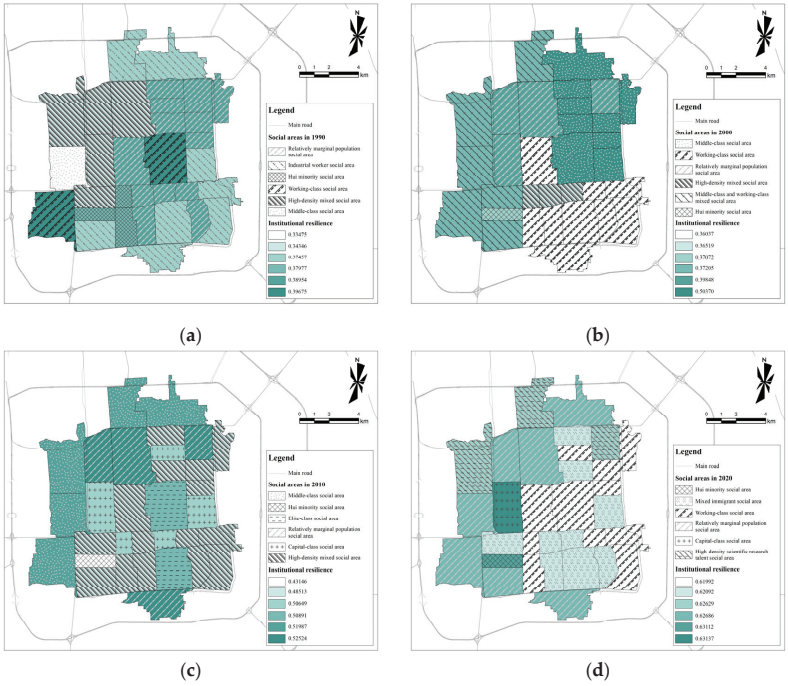


Figure 15. Distribution and evolution of the institutional resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

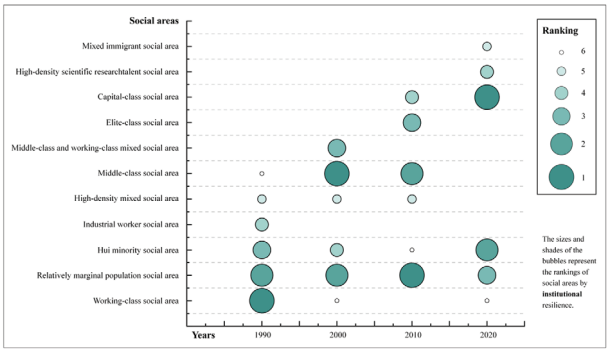


Figure 16. Bubble chart of the institutional resilience ranking changes across different social areas in Beijing's central area (1990–2020).

Social capital encompasses the total resources, both actual and potential, accessible through individuals' social networks, which is a critical dimension in discussions of socio-spatial resilience. The level of social capital resilience reflects the diversity and stability of internal connections within social groups and indicates their collective capacity for cooperation, mutual support, and resource mobilization in the face of risks [47–52]. This resilience serves as a strong internal impetus for groups when confronting challenges. During the study period, the central area of Beijing exhibited significant variations in social capital resilience across different social areas (See Figures 17 and 18). The middle-class social area consistently maintained high and stable social capital resilience, while the relatively marginal population social area experienced marked fluctuations. Additionally, the capital-class social area and Hui minority social area showed relative improvements in social capital resilience.

The middle-class social area has long demonstrated high levels of social capital resilience. During China's planned economy period (approximately 1949–1978), the welfare housing allocation system created a work–residence integration model, known as the *Danwei* (*Danwei* refers to a Chinese work unit that, during the socialist era, often provided not only employment but also housing and other amenities to its workers. The *Danwei* system was a cornerstone of urban life in socialist China, serving as more than just a workplace; it was a central organizing principle of daily life. This system significantly influenced the social and spatial organization of urban communities, where all aspects of life were closely tied to the workplace. However, by the 1990s and 2000s, the *Danwei* system had largely lost its central role in Chinese urban life, though remnants of it persist, particularly in older state-owned enterprises and government institutions.), in which workplace location dictated residential patterns [53,54]. It significantly influenced the social and spatial organization of urban communities, where all aspects of life were closely tied to the workplace. This arrangement persisted into the 1990s, with Beijing's central area still influenced by the dual forces of the *Danwei* system and the household registration system. Housing construction and the use of space remained constrained by these systems, intricately linking residential areas to workplaces. The middle-class social area was primarily concentrated in the Yuetan Block, home to numerous national and municipal government institutions. Residents often had dual roles as neighbors and colleagues, and shared similar educational levels of attainment and value systems, thereby fostering tightly knit, well-structured social networks. This multilayered social framework facilitated a strong sense of community, further reinforcing social ties and establishing stable social capital resilience. However, between 1990 and 2000, the functional upgrading of the central area, the promotion of housing commercialization policies, and the economic boom led to increased residential mobility among residents, which in turn contributed to the gentrification process. During this period, the original Dongcheng District became a focal

point for the renovation of dilapidated housing due to lower relocation costs. Commercial areas and high-end apartments replaced old buildings, attracting an influx of middle-class residents. The middle-class population and residential space expanded, with some local residents ascending to the new middle class while also drawing in many new middle-class migrants. This internal structural change contributed to a decline in social capital resilience. Nevertheless, the relatively favorable economic conditions of these communities and their active participation in social organizations fostered the formation of new social networks. Consequently, by 2000, the social capital resilience of the middle-class social area in central Beijing remained relatively high compared to other areas.

By 2010, the gentrification process in Beijing's central area had further accelerated, leading to the gradual migration of the middle class out of the inner-city core, to be replaced by a more stratified elite and capital class. The relatively brief history of these newly-formed communities likely resulted in less frequent interactions among residents. Moreover, the nature of this elite class, which often prioritizes work and professional commitments, contributed to weaker social bonds within the community. This limited their collective capacity to collaborate effectively when facing challenges, resulting in relatively lower levels of social capital resilience. However, due to the high spatial concentration and reduced population mobility within the capital-class social area, the initially weak social interactions among neighbors began to strengthen over time. This increased social cohesion helped mitigate the decline in social capital resilience by 2020. As a result, the social capital resilience in these areas eventually improved, reaching a relatively high level within Beijing's central area.

The social capital resilience in the relatively marginal social area has experienced complex fluctuations. In 1990, these marginal populations were dispersed, primarily concentrated in the former Dongcheng and Chongwen Districts, with a few in the former Xuanwu District. Historically, Beijing's inner city (between the Second Ring Road and the Forbidden City) was home to impoverished populations and ethnic minorities. As the economy flourished, the area attracted a significant influx of migrants, with some neighborhoods gradually evolving into key areas for the relatively marginal social area. The diversity and inclusiveness of the residential structure in these areas fostered frequent interactions and mutual assistance among residents, leading to relatively high levels of social capital resilience. Between 2000 and 2020, the spatial distribution of these areas remained relatively stable, with minimal areal redevelopment. The pre-existing strong social networks in these areas were preserved, maintaining high levels of social capital resilience.

Amid rapid gentrification and profound socio-spatial changes, the Hui minority social area in southwestern Beijing's central area has demonstrated unique residential stability. Centered around the Niujie Block, this area, rich in its historical and cultural heritage and characterized by distinct ethnic features, has maintained spatial stability due to high rates of residents returning to their original residential locations during urban renewal projects, allowing long-term neighborhood relationships to persist. However, significant differences in religious beliefs and lifestyles between the Hui population and other ethnic groups has led to challenges such as inadequate living conditions and insufficient resource allocation, resulting in relatively weak social capital resilience from 1990 to 2000. Over time, as the overall cultural literacy and socioeconomic status of ethnic minorities have improved, the Hui minority social area has not only overcome these challenges but also gained more opportunities for social participation, thereby strengthening internal social bonds. The strong cultural cohesion and community identity within the Hui minority social area has supported the rapid growth of social capital resilience. The shared religious beliefs and cultural background within the Hui community have also deepened spiritual ties among its members. In addition to the Hui population, the Niujie Block hosts a diverse mix of over 20 different ethnic minorities within its 1.44 square kilometers. This multicultural environment fosters frequent interactions among different ethnic groups, enhancing community cohesion and centripetal force, thereby constructing a stable and

vibrant social network. As a result, since 2010, this social area has consistently maintained the highest level of social capital resilience within Beijing's central area.

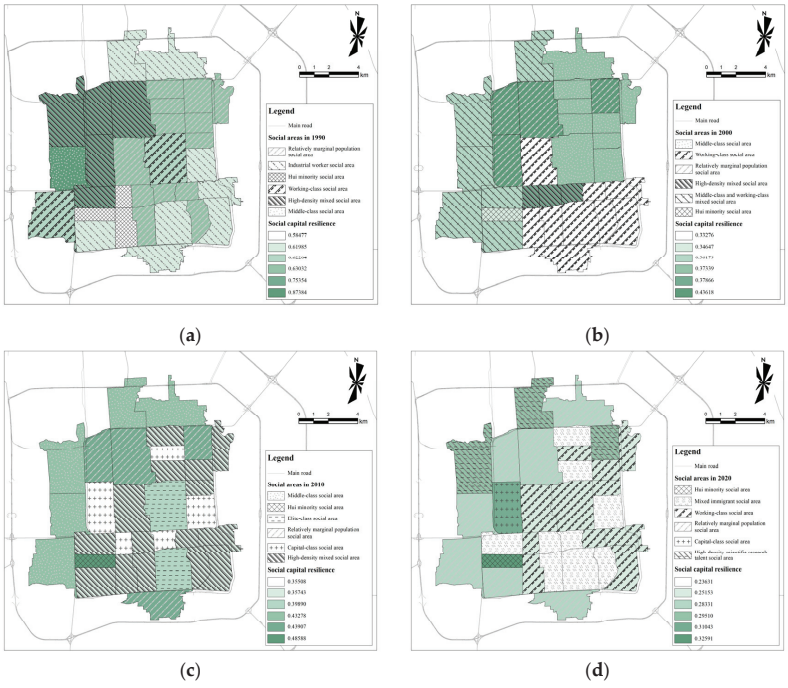


Figure 17. Distribution and evolution of the social capital resilience of different social areas in Beijing's central area across four time points. (**a**) 1990; (**b**) 2000; (**c**) 2010; and (**d**) 2020.

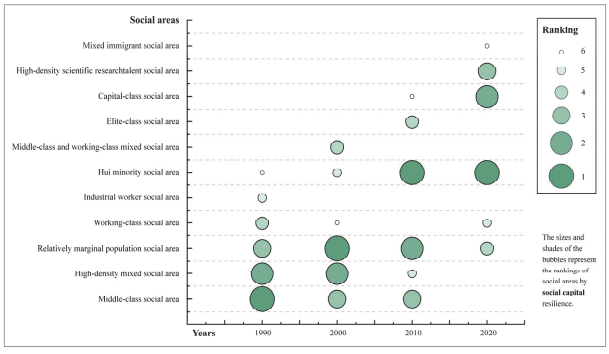


Figure 18. Bubble chart of the social capital resilience ranking changes across different social areas in Beijing's central area (1990–2020).

4. Discussion

Before the full impact of China's reform and 'opening-up' policies was felt, the *Danwei* and household registration systems, as part of the planned economy, restricted residents' occupational choices, residential locations, and freedom of movement. Socio-economic differences between residents were therefore relatively small, and their places of residence and work were closely intertwined, resulting in low population mobility. Consequently, residents easily formed close social ties through occupational affiliation or long-term cohabitation and geographic ties [55]. The overlap of the *Danwei* system of occupational

affiliation and the geographic relationship of being neighbors for generations built a deep emotional foundation, a strong identity, and robust collective cohesion among residents of such work-housing units, nurturing the high social capital resilience of social areas observed in 1990. From the late 1970s onwards, Chinese society entered a period of rapid transformation characterized by promotion of a social market economy, urbanization, the liberalization of labor mobility, and the commercialization of housing [56–58]. As a consequence, this period also saw rapid social differentiation and the formation of new social areas. The liberalization of the housing market increased residents' freedom of housing choice, and at the same time, its commercialization contributed to the hierarchical differentiation of urban communities. With increased freedom of movement within and across regions, residential segregation became more apparent, forming a new pattern marked by small-scale residential homogeneity and large-scale segregation [59]. From 1990 to 2000, the reorganization of social space and changes in residential structures disrupted existing social ties, leading to a sharp decline in social capital resilience [55]. The weakening of social interactions between individuals challenged the reconstruction of social relations and cohesion within communities, resulting in a slow recovery in social capital resilience in central Beijing's social areas between 2000 and 2010.

The homogeneity explored in this study refers to the convergence or similarity of different community residents in terms of their social background, cultural roots, and economic income levels within a given social area. It reflects the spatial manifestation of urban stratification and constitutes an opposing conceptual category to heterogeneity. There are two mainstream views on how homogeneity and heterogeneity shape social relations and affect the accumulation of social capital. One view posits that increased heterogeneity facilitates the exchange of knowledge and information, increases the potential for reciprocal behaviors, and is conducive to the accumulation of social capital [60–62]. The other view emphasizes that increased homogeneity stimulates members' psychological resonance and identity, promotes harmonious interactions through community participation, and builds a close social network, thereby contributing to the accumulation of social capital [63,64]. Some scholars, through practical research, have suggested that a community environment combining moderate homogeneity and heterogeneity provides the ideal route to achieve the in-depth development of social relations and the extensive accumulation of social capital [65–67]. Based on existing research by Chinese scholars, the mainstream view is that during China's economic and social transition, increased heterogeneity within the community negatively impacted the accumulation of social capital, weakened residents' sense of community identity and belonging, and led to decentralized and fragmented community management [68–73]. This view is consistent with the findings of this study.

In this study, the high-density mixed social area exhibited the most complex and heterogeneous demographic structure. During China's period of transition, this area's social capital resilience declined significantly, making it the only social area to witness a decline in social capital resilience, while many other social areas in the central area experienced recovery from 2000 to 2010. In contrast, the Hui minority social area showed the highest percentage in social capital resilience recovery between 2000 and 2010 due to its long history of settlement and strong homogeneity. Although the capital-class social area also has a high degree of homogeneity, its social capital resilience was relatively low in 2010. This can be attributed to a lack of both participation in community activities and a common cultural identity arising from nuanced differences in the socio-economic conditions of its residents, thereby impeding the formation of strong social ties. In 2020, the social areas within the central area experienced a significant decline in specific indicators, resulting in a general weakening of social capital resilience. However, the capital-class social area exhibited the least decline in social capital resilience compared to other types of social areas. This is closely related to the fact that after a certain degree of contraction in the original settlement space, the interactions between residents increased, and neighborhood ties were strengthened and solidified over time. This highlights the complexity and multidimensionality of the influence of homogeneity in constructing social capital resilience within social areas.

The strength of social capital resilience is not only related to a community's typological characteristics and the degree of homogeneity among its residents but is also affected by the intertwined influences of the broader socio-economic context.

The theoretical emphasis on a high degree of socio-spatial mixing has perhaps been overemphasized in past research, and its appropriateness in real social contexts is questionable [74–76]. When significant differences exist between communities, particularly when they have hugely different values and interests, forcing them into the same spatial boundary can easily lead to serious disagreements. This phenomenon is particularly prominent in the mixed construction of commercial and affordable housing within the same communities. Developers often build a 'separating wall' to distinguish between these two types of communities [77]. Differentiated treatment in living environments, facilities, and community management can lead to physical separation, resulting in disagreements over the sharing of public space and the use of facilities [78,79]. These conflicts can be difficult to reconcile and may eventually evolve into violent confrontations. Since 2017, there have been frequent incidents of conflict around separating walls in mixed-housing neighborhoods in Beijing, Shenzhen, Guangzhou, and other Chinese cities. Therefore, in certain contexts, moderate spatial segregation and functional differentiation should be re-evaluated, as they may serve as effective means to foster community harmony and mitigate potential conflicts, rather than being seen as forms of social exclusion. Based on the findings of this study, communities that were still significantly shaped by the *Danwei* system in 1990 exhibited positive trends in social capital resilience. It is therefore to be recommended that cities integrate the development of industrial parks and residential areas for employees into the planning of new development zones, especially for low-pollution or non-polluting tertiary industry parks. Integrating this approach with the currently promoted '15 min' urban life cycle will enhance the job–housing balance. This strategy will also significantly reduce carbon emissions and support sustainable urban development [80]. Additionally, it has the potential to greatly enhance community participation, a sense of belonging, and interpersonal interactions, cultivating a high degree of social capital resilience. This approach could enable residents to achieve a true sense of stability and well-being in urban life.

Although this study has, to a certain extent, revealed the evolutionary characteristics of multidimensional resilience in the central area of Beijing over the 30-year period from 1990 to 2020, it possesses several limitations that need to be addressed and further validated by subsequent studies. Due to the spatial resolution constraints of the publicly available data from the Seventh National Population Census of 2020, significant quantities of data are only available at the district level, lacking detail at the block level. This resulted in a lower degree of refinement of the 2020 data compared to that of 1990–2010, affecting the continuity and accuracy of the study to some extent. Although the construction of the evaluation index system in this study is generally logical and reasonable, the selection and design of individual indicators remain debatable. The indicators used in the evaluation dimension of social capital resilience are more traditional and fail to fully capture the complexity of the dynamic changes affecting modern society. Given the development of the internet and big data, it becomes necessary to introduce more diversified data sources, such as mobile communication data and social network data, to provide a more detailed and comprehensive depiction of community connection networks and to evaluate social capital resilience more accurately [81,82]. In evaluating population resilience, this study's treatment of the two indicators, i.e., population density and living space per capita, has failed to fully explore their positive and negative aspects. These indicators should be regarded as moderate; values that are either too high or too low are not conducive to resilience. Morphological resilience indicators could also be enriched in the future by extracting key information, such as road network structure, through high-precision remote sensing images to enrich their dimensional representations and achieve a more detailed and accurate analysis [83]. Another significant issue is that, as the core of an international metropolis, the resilience of Beijing's central area is also obviously influenced

by short-term tourists and long-term foreign residents, though their specific impacts are beyond this study's scope. Future research could expand to include these groups, offering a fuller understanding of the complexity and multidimensional nature of resilience in central Beijing.

Despite this study exploring the entropy weight method and set pair analysis, the current conclusions are mainly based on a relatively idealized single case study. The novelty of this paper lies in its selection of social areas as the unit of analysis for the resilience assessment of metropolitan core areas. In scenarios involving long time spans and multiple time points, social areas composed of similar social groups tend to exhibit spatial discontinuities. However, the settlement characteristics of the same social group can still be accurately recognized in different spatial locations. Therefore, exploring the multidimensional resilience of such social areas is of significant research value. Considering the unique nature and complexity of metropolitan core areas, the manifestation of multidimensional resilience and the characteristics brought about by the homogeneity or heterogeneity of social groups within different metropolitan areas over the same time period may vary. A multi-city study using a multidimensional comparative analysis approach would provide a key route to further deepening practical research. Empirical validation in more complex contexts would help improve and verify the generalizability and replicability of the analytical framework proposed in this study [84–86], thereby establishing potentially more instructive resilience assessment and governance strategies.

5. Conclusions

Resilience, as an emerging concept for addressing uncertainty and achieving sustainable development, has gradually transitioned from theory to practice. This shift is evident in the resilience assessments and constructions being undertaken from the national to the city and community level. However, relying solely on traditional administrative divisions for resilience assessment can result in scale and scope discrepancies. This study examined the central area of Beijing, the capital of a rapidly transforming China, and explored a multifaceted resilience assessment regime based on social area units. The findings indicated that, compared to traditional administrative boundaries, socio-spatial divisions that emphasize the network structure of social relations and the dynamic changes within social areas might be more suitable as fundamental units for resilience assessment. These divisions can be dynamically adjusted over time, more flexibly reflecting the true conditions within civil society, rather than relying solely on physical space inferences.

Against the backdrop of China's rapid transition from a planned economy to a social market economy, Beijing's central area underwent extensive renovation of its ancient city and significant gentrification from 1990 to 2000. During this period, the overall resilience of the central area and all social areas steadily increased, while social capital resilience notably declined. From 2000 to 2010, although residents in various social areas endeavored to rebuild their networks of connections, leading to some recovery in social capital resilience, it was insufficient to compensate for the losses caused by urban renovation. Between 2000 and 2010, the high-density mixed social area, due to its extraordinarily complex and heterogeneous demographic structure, was the only social area where social capital resilience declined. Its reconstruction and restoration of social capital resilience faced significant challenges. By 2020, the overall level of social capital resilience of the central area had further decreased. Meanwhile, the socio-spatial structure within the central area underwent changes, with some new social areas being delineated. Among these new social areas, social capital resilience was relatively high in the high-density scientific research talent social area, whereas it was lowest in the mixed immigrant social area, which had the most complex demographic composition. Contrary to traditional beliefs that have emphasized the benefits of socio-spatial heterogeneity, this study found that social areas with lower heterogeneity and higher homogeneity in Beijing's central area during the transition period exhibited higher overall resilience and a more positive trend in the development of their social capital resilience. In contrast, high-density mixed social

areas encountered significant obstacles in fostering resilience. These conclusions provide innovative perspectives and references for cities and communities that may aid enhanced resilience in the face of future uncertainties, and for policymakers in selecting appropriate governance strategies.

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Appendix A

Table A1. Beijing's central area resilience evaluation indicator system.

Dimension	Indicators	Attribute	Weight
Economy (0.2143)	Fiscal revenue per unit area (10,000 yuan/km^2)	+	0.0327
	Per capita fixed asset investment (Chinese yuan)	+	0.0230
	Urban registered unemployment rate (%)	−	0.0061
	Average wage of on-the-job employees in urban areas (yuan)	+	0.0331
	Per capita disposable income of urban residents (yuan)	+	0.0325
	Consumer price index (CPI, 1980 = 100)	−	0.0107
	Engel coefficient (%)	−	0.0080
	Gini coefficient of urban households	−	0.0104
	Proportion of female employment in the labor force (%)	+	0.0025
	Number of persons in charge of state organs, party and mass organizations, enterprises, and public institutions (%)	+	0.0032
	Per capita retail sales of consumer goods (Chinese yuan)	+	0.0342
	Per capita actual utilization of foreign capital (Chinese yuan)	+	0.0179
Population (0.0682)	Percentage of population with college education or above (%)	+	0.0090
	Percentage of population aged 60 and over (%)	−	0.0032
	Percentage of population under 15 years old (%)	−	0.0020
	Natural change rate in registered population (‰)	+	0.0032
	Population density (persons/km^2)	+	0.0031
	Average household size (persons/household)	+	0.0035
	Infant mortality rate (%)	−	0.0104
	Living space per capita (m^2/person)	−	0.0089
	Sex ratio (Female = 100)	−	0.0007
	Percentage of ethnic minority population (%)	+	0.0087
	Proportion of population in commerce and service sectors (%)	+	0.0066
	Ratio of population with college education or above to population with high school education or below (%)	+	0.0090

Table A1. *Cont.*

Dimension	Indicators	Attribute	Weight
Institution (0.1555)	Human development index (HDI)	+	0.0109
	Employment elasticity coefficient	+	0.0048
	Number of technical transactions (in billion Chinese yuan)	+	0.0252
	Proportion of granted patents to individuals (%)	+	0.0115
	Number of administrative cases received by courts	−	0.0085
	Percentage of healthcare expenditure in fiscal expenditure (%)	+	0.0144
	Food hygiene compliance rate for catering units (%)	+	0.0055
	Average direct economic loss per fire incident	−	0.0065
	Number of proposals submitted by members of the CPPCC (Chinese People's Political Consultative Conference)	+	0.0165
	Total number of certificates issued by notary offices	+	0.0407
	Corruption Perceptions Index (CPI)	+	0.0098
	Political fragmentation level (%)	−	0.0012
Social Capital (0.1412)	Percentage of family households versus total households (%)	+	0.0012
	Number of children enrolled in childcare institutions	+	0.0105
	Proportion of educational expenditure versus total local financial expenditure (%)	+	0.0087
	Proportion of urban residents enjoying minimum social security versus the total permanent registered population (%)	−	0.0090
	Number of religious professionals per 100,000 people	+	0.0411
	Number of social organization members per 10,000 people	+	0.0264
	Number of trade union members per 10,000 people	+	0.0090
	Number of full-time women's federation cadres per 10,000 persons	+	0.0096
	Percentage of resident population classed as permanent (%)	+	0.0041
	Percentage of migrants from other provinces versus total number of permanent residents (%)	−	0.0026
	Number of mediators per 10,000 people	+	0.0088
	Clearance rate for criminal cases (%)	+	0.0100
Ecology (0.1399)	Number of trees per square kilometer at year-end	+	0.0055
	Number of lawns per square kilometer at year-end	+	0.0064
	Green coverage rate of built-up areas (%)	+	0.0046
	Percentage of days with air quality at grade II or better (%)	+	0.0095
	Daily average atmospheric sulfur dioxide content (mg/m^2)	−	0.0077
	Urban domestic wastewater treatment rate (%)	+	0.0105
	Comprehensive utilization rate of industrial solid waste (%)	+	0.0119
	Average regional environmental noise (dB)	−	0.0086
	Proportion of environmental investment in urban infrastructure investment (%)	+	0.0101
	Energy consumption per 10,000 Chinese yuan of GDP (tons of standard coal)	−	0.0085
	Energy consumption elasticity coefficient	−	0.0341
	Electricity consumption elasticity coefficient	−	0.0225
Engineering (0.2413)	Per capita managed residential building area	+	0.0414
	Per capita passenger volume (people)	+	0.0116
	Per capita completed residential building area	+	0.0646
	Average number of hospital and clinic beds per 1000 persons	+	0.0053
	Power supply redundancy	+	0.0307
	Water supply redundancy	+	0.0114
	Proportion of district roads versus total urban area (%)	+	0.0148
	Proportion of infrastructure investment versus total social fixed asset investment (%)	+	0.0153
	Per capita passenger transport volume (persons)	+	0.0231
	Per capita freight transport volume (tons)	+	0.0144
	Average daily public transport rides per capita	+	0.0087

Table A1. *Cont.*

Dimension	Indicators	Attribute	Weight
Network (0.0114)	Number of mobile phones per 10,000 households	+	0.0114
Morphology (0.0281)	Road network density (kilometers/square kilometers)	+	0.0281

References

1. Leach, M. Re–Framing Resilience: A Symposium Report. In *Working Paper 13*; STEPS Centre: Brighton, UK, 2008.
2. Foster, K.A. Regional resilience. In *How Do We Know It When We See It. Conference on Urban and Regional Policy and Its Effects*; Brookings Institution: Washington, DC, USA, 2010; Volume 4.
3. Martin-Breen, P.; Anderies, J.M. *Resilience: A Literature Review*; Institute of Development Studies: Brighton, UK, 2011.
4. Christopherson, S.; Michie, J.; Tyler, P. Regional resilience: Theoretical and empirical perspectives. *Camb. J. Reg. Econ. Soc.* **2010**, *3*, 3–10. [CrossRef]
5. Consultancy, W.C. *Demographia World Urban Areas (Built Up Urban Areas or World Agglomerations) 19th Annual Edition*; New Geography; Wendel Cox Consultancy: Los Angeles, CA, USA, 2023; p. 5.
6. Zheng, Y.; Xin-Lu, X.; Chen-Zhen, L.; Mou, W.; Xiao-Jia, H. Development as adaptation: Framing and measuring urban resilience in Beijing. *Adv. Clim. Chang. Res.* **2018**, *9*, 234–242. [CrossRef]
7. Liu, L.; Lei, Y.; Zhuang, M.; Ding, S. The impact of climate change on urban resilience in the Beijing-Tianjin-Hebei region. *Sci. Total Environ.* **2022**, *827*, 154157. [CrossRef]
8. Capozzo, M.; Rizzi, A.; Cimellaro, G.; Domaneschi, M.; Barbosa, A.; Cox, D. Multi-hazard resilience assessment of a coastal community due to offshore earthquakes. *J. Earthq. Tsunami* **2019**, *13*, 1950008. [CrossRef]
9. Koren, D.; Rus, K. The potential of open space for enhancing urban seismic resilience: A literature review. *Sustainability* **2019**, *11*, 5942. [CrossRef]
10. Li, Z.; Zhang, X.; Ma, Y.; Feng, C.; Hajiyev, A. A multi-criteria decision making method for urban flood resilience evaluation with hybrid uncertainties. *Int. J. Disaster Risk Reduct.* **2019**, *36*, 101140. [CrossRef]
11. Zhong, M.; Lin, K.; Tang, G.; Zhang, Q.; Hong, Y.; Chen, X. A framework to evaluate community resilience to urban floods: A case study in three communities. *Sustainability* **2020**, *12*, 1521. [CrossRef]
12. Zhang, X.; Song, J.; Peng, J.; Wu, J. Landslides-oriented urban disaster resilience assessment—A case study in ShenZhen, China. *Sci. Total Environ.* **2019**, *661*, 95–106. [CrossRef]
13. Smith, N. *Uneven Development: Nature, Capital, and the Production of Space*; University of Georgia Press: Athens, GA, USA, 2010.
14. MacKinnon, D.; Derickson, K.D. From resilience to resourcefulness: A critique of resilience policy and activism. *Prog. Hum. Geogr.* **2013**, *37*, 253–270. [CrossRef]
15. Zhang, J.; Wang, T. Urban resilience under the COVID-19 pandemic: A quantitative assessment framework based on system dynamics. *Cities* **2023**, *136*, 104265. [CrossRef]
16. Lak, A.; Hakimian, P.; Sharifi, A. An evaluative model for assessing pandemic resilience at the neighborhood level: The case of Tehran. *Sustain. Cities Soc.* **2021**, *75*, 103410. [CrossRef] [PubMed]
17. Bruneau, M.; Chang, S.E.; Eguchi, R.T.; Lee, G.C.; O'Rourke, T.D.; Reinhorn, A.M.; Shinozuka, M.; Tierney, K.; Wallace, W.A.; Von Winterfeldt, D. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthq. Spectra* **2003**, *19*, 733–752. [CrossRef]
18. Allenby, B.; Fink, J. Toward inherently secure and resilient societies. *Science* **2005**, *309*, 1034–1036. [CrossRef]
19. Cutter, S.L.; Barnes, L.; Berry, M.; Burton, C.; Evans, E.; Tate, E.; Webb, J. A place-based model for understanding community resilience to natural disasters. *Glob. Environ. Chang.* **2008**, *18*, 598–606. [CrossRef]
20. Norris, F.H.; Stevens, S.P.; Pfefferbaum, B.; Wyche, K.F.; Pfefferbaum, R.L. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *Am. J. Community Psychol.* **2008**, *41*, 127–150. [CrossRef]
21. Cutter, S.L.; Burton, C.G.; Emrich, C.T. Disaster resilience indicators for benchmarking baseline conditions. *J. Homel. Secur. Emerg. Manag.* **2010**, *7*, 1–22. [CrossRef]
22. Pendall, R.; Foster, K.A.; Cowell, M. Resilience and regions: Building understanding of the metaphor. *Camb. J. Reg. Econ. Soc.* **2010**, *3*, 71–84. [CrossRef]
23. Sherrieb, K.; Norris, F.H.; Galea, S. Measuring capacities for community resilience. *Soc. Indic. Res.* **2010**, *99*, 227–247. [CrossRef]
24. Kulig, J.C.; Edge, D.S.; Townshend, I.; Lightfoot, N.; Reimer, W. Community resiliency: Emerging theoretical insights. *J. Community Psychol.* **2013**, *41*, 758–775. [CrossRef]
25. Cutter, S.L.; Ash, K.D.; Emrich, C.T. The geographies of community disaster resilience. *Glob. Environ. Chang.* **2014**, *29*, 65–77. [CrossRef]
26. Wang, Z.; Deng, X.; Wong, C.; Li, Z.; Chen, J. Learning urban resilience from a social-economic-ecological system perspective: A case study of Beijing from 1978 to 2015. *J. Clean. Prod.* **2018**, *183*, 343–357. [CrossRef]

27. Da Mata Martins, M.C.; Da Silva, A.N.R.; Pinto, N. An indicator-based methodology for assessing resilience in urban mobility. *Transp. Res. Part D Transp. Environ.* **2019**, *77*, 352–363. [CrossRef]
28. Kammouh, O.; Zamani Noori, A.; Cimellaro, G.P.; Mahin, S.A. Resilience assessment of urban communities. *ASCE-ASME J. Risk Uncertain. Eng. Syst. Part A Civ. Eng.* **2019**, *5*, 04019002.
29. Feng, X.; Xiu, C.; Bai, L.; Zhong, Y.; Wei, Y. Comprehensive evaluation of urban resilience based on the perspective of landscape pattern: A case study of Shenyang city. *Cities* **2020**, *104*, 102722. [CrossRef]
30. Sajjad, M.; Chan, J.C.; Chopra, S.S. Rethinking disaster resilience in high-density cities: Towards an urban resilience knowledge system. *Sustain. Cities Soc.* **2021**, *69*, 102850. [CrossRef]
31. Shi, Y.; Zhai, G.; Xu, L.; Zhou, S.; Lu, Y.; Liu, H.; Huang, W. Assessment methods of urban system resilience: From the perspective of complex adaptive system theory. *Cities* **2021**, *112*, 103141. [CrossRef]
32. Liu, L.; Lei, Y.; Fath, B.D.; Hubacek, K.; Yao, H.; Liu, W. The spatio-temporal dynamics of urban resilience in China's capital cities. *J. Clean. Prod.* **2022**, *379*, 134400. [CrossRef]
33. Lu, H.; Zhang, C.; Jiao, L.; Wei, Y.; Zhang, Y. Analysis on the spatial-temporal evolution of urban agglomeration resilience: A case study in Chengdu-Chongqing Urban Agglomeration, China. *Int. J. Disaster Risk Reduct.* **2022**, *79*, 103167. [CrossRef]
34. Serdar, M.Z.; Koç, M.; Al-Ghamdi, S.G. Urban transportation networks resilience: Indicators, disturbances, and assessment methods. *Sustain. Cities Soc.* **2022**, *76*, 103452. [CrossRef]
35. Ye, C.; Hu, M.; Lu, L.; Dong, Q.; Gu, M. Spatio-temporal evolution and factor explanatory power analysis of urban resilience in the Yangtze River Economic Belt. *Geogr. Sustain.* **2022**, *3*, 299–311. [CrossRef]
36. Zhao, R.; Fang, C.; Liu, J.; Zhang, L. The evaluation and obstacle analysis of urban resilience from the multidimensional perspective in Chinese cities. *Sustain. Cities Soc.* **2022**, *86*, 104160. [CrossRef]
37. Wang, H.; Liu, Z.; Zhou, Y. Assessing urban resilience in China from the perspective of socioeconomic and ecological sustainability. *Environ. Impact Assess. Rev.* **2023**, *102*, 107163. [CrossRef]
38. Ma, L.; Zhao, J.H.; Hong, M.; Chen, L.L. Application of set pair analysis model based on entropy weight for comprehensive evaluation of water resources carrying capacity. *Appl. Mech. Mater.* **2012**, *195*, 764–769. [CrossRef]
39. Su, F.; Li, P.; He, X.; Elumalai, V. Set pair analysis in earth and environmental sciences: Development, challenges, and future prospects. *Expo. Health* **2020**, *12*, 343–354. [CrossRef]
40. Su, M.; Yang, Z.; Chen, B. Set pair analysis for urban ecosystem health assessment. *Commun. Nonlinear Sci. Numer. Simul.* **2009**, *14*, 1773–1780. [CrossRef]
41. Su, F.; Zhang, P. Vulnerability assessment of petroleum city's economic system based on set pair analysis: A case study of daqing city. *Acta Geogr. Sin.* **2010**, *65*, 454–464.
42. Su, F.; Chen, Y.; Zhang, P. Vulnerability assessment of tourism city's economic system based on the set pair analysis: A case study of Zhoushan city. *Sci. Geogr. Sin.* **2013**, *33*, 538–544.
43. Xu, C.; An, Q.; Guo, Z.; Yu, X.; Zhang, J.; Tang, K. Comparative Study on Socio-Spatial Structures of the Typical Plain Cities of Chengdu and Beijing in Transitional China. *Sustainability* **2023**, *15*, 4364. [CrossRef]
44. Bai, B. Analysis of the dynamics of Chinese housing policy changes since Reform and Opening-up: From the perspective of Multiple-Streams framework. *J. Public Manag.* **2010**, *7*, 76–85.
45. Young, O.R. Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes. *Glob. Environ. Chang.* **2010**, *20*, 378–385. [CrossRef]
46. Ribeiro, P.J.G.; Gonçalves, L.A.P.J. Urban resilience: A conceptual framework. *Sustain. Cities Soc.* **2019**, *50*, 101625. [CrossRef]
47. Coleman, J.S. *Foundations of Social Theory*; Harvard University Press: Cambridge, MA, USA, 1994.
48. Lochner, K.; Kawachi, I.; Kennedy, B.P. Social capital: A guide to its measurement. *Health Place* **1999**, *5*, 259–270. [CrossRef] [PubMed]
49. Pretty, J.; Ward, H. Social capital and the environment. *World Dev.* **2001**, *29*, 209–227. [CrossRef]
50. Putnam, R. Social capital: Measurement and consequences. *Can. J. Policy Res.* **2001**, *2*, 41–51.
51. Fukuyama, F. Social capital and development. *SAIS Rev.* **2002**, *22*, 23–37. [CrossRef]
52. Sandefur, R.L.; Laumann, E.O. A paradigm for social capital. In *Rationality and Society*; Routledge: London, UK, 1998; Volume 10, pp. 481–501.
53. Bjorklund, E. The Danwei: Socio-spatial characteristics of work units in China's urban society. *Econ. Geogr.* **1986**, *62*, 19–29. [CrossRef]
54. Bray, D. *Social Space and Governance in Urban China: The Danwei System from Origins to Reform*; Stanford University Press: California, CA, USA, 2005.
55. Cai, H.; He, X. Urban community heterogeneity and cohesion: A study of neighborhood relationships. *J. Sun Yat-Sen Univ. (Soc. Sci. Ed.)* **2014**, *54*, 133–151.
56. Huang, Y. From work-unit compounds to gated communities: Housing inequality and residential segregation in transitional Beijing. In *Restructuring the Chinese City*; Routledge: London, UK; New York, NY, USA, 2004; pp. 172–198.
57. Zhang, C.; Chai, Y.; Chen, L. The evolution from Danwei community to citizen community: Case study of Tongrentang in Beijing. *Urban Plan. Int.* **2009**, *24*, 33–36.
58. Chai, Y.; Zhang, C. Geographical approach to Danwei in Chinese cities: A key to understand the transition of urban China. *Urban Plan. Int.* **2009**, *24*, 2–6.

59. Mu, X.; Yang, W. Homogeneity of habitation and the community reconstruction in urban spatial evolvement in big cities: A case study of three mega-communities in Beijing. *Hum. Geogr.* **2013**, *28*, 24–30.
60. Narayan-Parker, D. *Voices of the Poor: Poverty and Social Capital in Tanzania*; ESD Studies and Monographs Series; World Bank Publications: Washington, DC, USA, 1997; Volume 20.
61. Stolle, D.; Rochon, T.R. Are all associations alike? Member diversity, associational type, and the creation of social capital. *Am. Behav. Sci.* **1998**, *42*, 47–65. [CrossRef]
62. Grootaert, C. *Social Capital, Household Welfare and Poverty in Indonesia*; Local Level Institutions Working Paper 6; World Bank Publications, Social Development Department: Washington, DC, USA, 1999.
63. Alesina, A.; La Ferrara, E. Participation in heterogeneous communities. *Q. J. Econ.* **2000**, *115*, 847–904. [CrossRef]
64. Alesina, A.; La Ferrara, E. Who trusts others? *J. Public Econ.* **2002**, *85*, 207–234. [CrossRef]
65. Gans, H.J. The balanced community: Homogeneity or heterogeneity in residential areas? *J. Am. Inst. Plan.* **1961**, *27*, 176–184. [CrossRef]
66. Majka, T.J.; Donnelly, P.G. Cohesiveness within a heterogeneous urban neighborhood: Implications for community in a diverse setting. *J. Urban Aff.* **1988**, *10*, 141–159. [CrossRef]
67. Gans, H.J. *The Levittowners: Ways of Life and Politics in a New Suburban Community*; Columbia University Press: New York, NY, USA, 2017.
68. Wang, Y. A case study on urban community in Shanghai community classification spatial distribution and changing tendencies. *Urban Plan. Forum* **2002**, *6*, 33–40+79.
69. Li, J.; Huang, R.; Feng, A. A study of urban community heterogeneity and neighborhood socialcapital. *Fudan J. (Soc. Sci. Ed.)* **2007**, *5*, 67–73.
70. Sun, B. Community toward heterogeneous structure: The case of a danwei block. *Nanjing J. Soc. Sci.* **2012**, *9*, 49–54.
71. He, X.; Liu, P. Reasearch on heterogeneous social structure and neighborhood relationship in urban communities. *Hum. Geogr.* **2016**, *31*, 1–9.
72. Cai, H.; Zhang, Y. Urban community heterogeneity and integration: An analysis based on the 2014 China Labor Force Dynamics Survey. *Soc. Sci. Front.* **2017**, 182–193.
73. Liu, Y.; He, S. Unpacking the heterogeneity of poor neighbourhoods and neighbouring in large Chinese cities. *Area Dev. Policy* **2017**, *2*, 294–313. [CrossRef]
74. Arthurson, K. Creating inclusive communities through balancing social mix: A critical relationship or tenuous link? *Urban Policy Res.* **2002**, *20*, 245–261. [CrossRef]
75. Bolt, G.; Phillips, D.; Van Kempen, R. Housing policy, (de)segregation and social mixing: An international perspective. *Housing Studies.* **2010**, *25*, 129–135. [CrossRef]
76. Bacqué, M.H.; Fijalkow, Y.; Launay, L.; Vermeersch, S. Social mix policies in Paris: Discourses, policies and social effects. *Int. J. Urban Reg. Res.* **2011**, *35*, 256–273. [CrossRef]
77. Ye, D.; Chen, S.; Zhang, J. Research on living conflict of affordable housing community from the mixed living perspective: A case study of R community in Fuzhou city. *Mod. Urban Res.* **2023**, *10*, 68–74.
78. Lv, C. Conflicts and integration of different classes' living styles in big cities: Theory, practice and introspection of housing mix and social mix. *J. Harbin Inst. Technol. (Soc. Sci. Ed.)* **2019**, *21*, 47–53.
79. Gu, Y. The declining of 'Publicity' in urban mixed community and its reconstruction. *Study Pract.* **2018**, *7*, 92–99.
80. Wang, D.; Chai, Y. The jobs–housing relationship and commuting in Beijing, China: The legacy of Danwei. *J. Transp. Geogr.* **2009**, *17*, 30–38. [CrossRef]
81. Xie, L.; Pinto, J.; Zhong, B. Building community resilience on social media to help recover from the COVID-19 pandemic. *Comput. Hum. Behav.* **2022**, *134*, 107294. [CrossRef] [PubMed]
82. Liu, Y.; Wang, X.; Song, C.; Chen, J.; Shu, H.; Wu, M.; Guo, S.; Huang, Q.; Pei, T. Quantifying human mobility resilience to the COVID-19 pandemic: A case study of Beijing, China. *Sustain. Cities Soc.* **2023**, *89*, 104314. [CrossRef] [PubMed]
83. Zhang, S.; Lei, J.; Zhang, X.; Tong, Y.; Lu, D.; Fan, L.; Duan, Z. Assessment and optimization of urban spatial resilience from the perspective of life circle: A case study of Urumqi, NW China. *Sustain. Cities Soc.* **2024**, *109*, 105527. [CrossRef]
84. Zhang, L.; Zhao, J.; Liu, J.; Chen, K. Community disaster resilience in the COVID-19 outbreak: Insights from shanghai's experience in china. *Risk Manag. Healthc. Policy* **2021**, *13*, 3259–3270. [CrossRef]
85. Hu, X.; Li, L.; Dong, K. What matters for regional economic resilience amid COVID-19? Evidence from cities in Northeast China. *Cities* **2022**, *120*, 103440. [CrossRef] [PubMed]
86. Li, S.; Chen, P.; Hui, F.; Gong, M. Evaluating urban vitality and resilience under the influence of the COVID-19 pandemic from a mobility perspective: A case study in Shenzhen, China. *J. Transp. Geogr.* **2024**, *117*, 103886. [CrossRef]

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An Approach to Analyzing Migration Flow and House Price Data: Exploring Spatial Linkages between Flow, Price, Distance, Age at the Local Level

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Abstract: This paper is intended to elucidate the efficacy of employing a Geographic Information Systems (GIS) methodology to investigate the spatial interrelations among migration flows, housing prices, age demographics, and geographical distances. Utilizing data on migration flows and housing prices from Greater Manchester, UK, in 2011, in this study, we performed statistical analyses and generated a suite of visual mappings to illustrate the spatial dynamics between migration patterns, distances, age brackets, and the segmentation of migration destinations by housing price tiers. The findings reveal pronounced spatial associations among migration destinations, underscored by the interplay of housing price levels with age categories, distance intervals, or the origination points tied to specific housing price ranges. This GIS-based analytical framework offers policy-makers and urban planners a powerful tool for discerning distinct migration trends and locales, thereby facilitating more informed decision-making processes.

Keywords: geographic information systems (GIS); migration flows; housing prices; spatial analysis; age demographics; urban planning

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1. Introduction

Migration exerts a significant influence on population dynamics, public services, and the socio-economic landscape, necessitating an in-depth analysis of household structures to inform policy-makers and service providers for future strategic planning [1]. An understanding of the economic and social determinants affecting migration dynamics is critical, requiring an examination of the scale and dynamics of household relocations across different regions [2].

The relationship between distance, age, and house price significantly influences migration patterns and local sustainability. Research indicates that younger populations tend to migrate shorter distances, often driven by affordability and job opportunities, which are closely tied to house prices in urban areas [3]. Conversely, older individuals may seek to relocate to suburban or rural areas, where housing is more affordable, impacting local demographics and sustainability efforts [4]. Moreover, house prices can deter migration, particularly for younger individuals, who face financial constraints, leading to stagnation in urban centers and potential decline in local economies [5]. This dynamic creates a feedback loop in which high house prices exacerbate distance-related migration challenges, ultimately affecting community sustainability and resource allocation.

Although previous research highlighted the impact of house prices and age demographics on migration trends, emphasizing the importance of housing affordability, locational preferences, and distance [6–8], there remains a notable gap in comprehending the spatial dynamics that connect migration destinations with the age of migrants and house price levels. This deficiency underscores the need for further research into how factors

such as age, geographical distance, and housing affordability influence migration patterns in various contexts. In this paper, we aim to answer the following questions: How do house price levels in migration areas correlate with household characteristics such as age, migration distance, and previous areas categorized by house price levels, and what are the policy implications and contributions to the literature on migration patterns?

In the UK, the Office for National Statistics conducts a comprehensive census every ten years. The 2011 Census provided detailed insights into demographic changes, housing, and employment shifts, all of which are crucial for informing policy and planning. Given the public availability of migration data from the Census, this source of migration information is invaluable for exploring population trends and patterns at both national and subnational levels [9]. Utilizing this dataset, previous research was conducted to elucidate the dynamics of migration flows, their temporal changes, and the significance of distance analysis [2,10]. Additionally, this dataset is often integrated with other datasets to examine the influence of social and economic factors on household mobility [7,11,12]. Within this context, house price data emerge as a critical variable. However, the existing body of migration studies that investigate the spatial connections between house price levels and migration flows is relatively sparse. Consequently, there is a significant opportunity to explore the spatial relationships between house price levels and migration flows, to ascertain whether there is a correlation between the magnitude of mobility flows and house price levels, and to determine whether there is a relationship between migration distance ranges, household age ranges, and the levels of house prices.

In this study, we investigate migration patterns within the Greater Manchester area, UK, focusing on their correlation with housing price levels, household age, and migration distance. Utilizing migration flow data and housing price information from 2011, statistical techniques such as cross-tabulation analysis and Chi-squared tests are employed alongside Geographic Information System (GIS) analysis. This combined approach is applied to identify significant spatial relationships between migration destinations and household characteristics. GIS technology facilitates the creation of detailed maps, illustrating spatial distribution patterns and highlighting connections between migration destinations and variables of interest [13]. Ultimately, the study is designed to contribute to the understanding of migration dynamics and offer insights for policy-making in housing and urban development within the region [12].

To conduct the research, we propose the following hypotheses:

Hypothesis 1. *There is a significant correlation between housing price levels and migration distances, such that higher housing prices are associated with shorter migration distances.*

Hypothesis 2. *Age demographics influence migration patterns, with certain age groups showing distinct preferences for regions with varying housing prices.*

Hypothesis 3. *The relationship between migration flows and housing prices varies by geographic location within Greater Manchester, with specific areas demonstrating stronger associations.*

This research showcases the effectiveness of GIS techniques in elucidating the intricate spatial relationships among migration patterns, age groups, and housing prices. A key breakthrough of this study is its application of GIS technologies to reveal the complex web of connections between various factors influencing migration, including housing affordability, demographic shifts, and the distances over which populations move. By graphically representing regions with pronounced migration challenges, GIS enables the formulation of targeted policy measures. Furthermore, the adept use of GIS to analyze extensive datasets on housing prices and migration paths underscores its critical role in dissecting the nuances of migration trends, offering a fresh lens through which to view the complexities of migration behavior. This study significantly enriches the field of migration research by illuminating the local-level spatial dynamics between household migrations and housing prices. By underscoring the utility of GIS in exploring the spatial dynamics of migration catalysts and housing economics, it not only expands the academic discourse but

also supplies practical insights for those in urban planning, policy-making, and migration studies. The introduction of a GIS-centric analytical framework represents a pivotal step forward, allowing for the strategic pinpointing and mitigation of issues in areas heavily affected by migration, thus paving the way for spatially informed solutions to migration-related challenges.

2. Literature Review

Predicting population dynamics accurately is crucial for governments worldwide to ensure the provision of adequate services. Efforts have often centered around household projections, utilizing models that incorporate social, economic, and life-cycle factors [14]. Enhancements in model robustness have been sought through the examination of life-course events, housing dissatisfaction, and the mobility intentions and decisions of diverse household groups [15,16]. By the late 1990s, research had delved into how age demographics influence migration decisions, particularly among young individuals, families, retirees, and the elderly [17]. Social and cultural determinants, such as employment opportunities, housing quality, environmental conditions, public policies, and ethnic background, have also been identified as significant [17]. Presently, we have created a modelling framework and techniques to analyze and forecast the increase in population and changes in housing density, taking into account the choices made by individuals in three different age groups. However, while these studies provide valuable insights, they primarily employ traditional statistical approaches, with a noted deficiency in spatial analysis techniques for the visual exploration of migration patterns and trends.

In demographic research, the focus often centers on age structure as a crucial factor. Urbanization trends indicate that cities will continue to expand, with significant implications for housing wealth driven by shifts in resident age demographics. Migration played a pivotal role in shaping population patterns and age structures, with concerns raised in the literature about the impact of aging populations on house prices [18–20]. Studies suggested that working-age households exhibit greater housing demand compared to retirees [21–23]. One study found a negative correlation between old-age dependency ratios and real house price growth [24]. Furthermore, specific demographic groups, such as married couples and cohabitors, exhibited varying probabilities of homeownership across age groups [25], contributing to demand for property acquisition. In summary, migration data categorized by age shed light on the relationship between migration flows and housing demand.

Recent research underscored the significant impact of age on migration patterns in a global context. Feng and Wang [26] found that migration distances vary with age, with retirees moving based on lifestyle changes or family proximity, and older retirees opting for shorter moves for care or downsizing reasons in England. Raymer et al. [27] highlighted the effects of older population migration on regional systems and demographics in the European Union. Levy and Mussida [28] noted that young and middle-aged individuals moved for education, career, or family, whereas retirees relocated for lifestyle improvements in European countries. Bell et al. [29] investigated global internal migration trends, emphasizing age as a key factor in mobility for a wider range of countries around the world [30]. A decrease in the proportion of individuals in the appropriate age group for home buying, along with shifts in family structures due to aging populations, directly impacted housing prices in China [30]. Collectively, these findings highlighted the need to consider age-related demographic changes in migration and urban development studies across countries.

In the UK, the Office for National Statistics (ONS) disseminates census data through official websites and various public channels. With access to census-based internal migration data, researchers have increasingly focused on analyzing spatial migration patterns and trends [2,9,10,31]. These migration data are valuable for understanding individuals' current and previous locations [9]. Employing a visual approach has proven useful for investigating trends and patterns within the census dataset, aiding in the identification of problematic migration patterns and their temporal changes. Notably, studies by Champion

and Shuttleworth [32], Kalogirou [10], and Chen et al. [31] have explored internal mobility flows in the UK, revealing national and sub-national migration trends. Stillwell et al. [2] stressed the importance of examining migration trends at regional and local levels over shorter time spans. Such research aids policy-makers and service providers in monitoring and addressing problematic migration patterns effectively. However, these studies often lack insight into the motivations behind movement and other factors associated with household mobility. Therefore, integrating census migration data with other datasets, such as those on housing prices, can offer a more comprehensive understanding of spatial linkages between migration flows and socioeconomic factors in migration areas. In our research paper, we merge census and house price datasets to provide insights into the spatial dynamics of migration and housing prices.

The integration of mobility data with socio-economic datasets in previous research has shed light on the spatial dynamics among regions characterized by distinct socio-economic profiles through the study of migration patterns. Studies such as those by Ferrari and Rae have unveiled the link between housing affordability and migration trends, demonstrating how area-level economic conditions influence residential mobility [12]. Hincks further explored migration flows against the backdrop of socio-economic disparities, employing visual tools to detail the spatial relationships between areas of varying economic health [33]. Subsequent work by Darlington-Pollock et al. [11] and Lomax et al. [7] identified the critical role of migration distance, correlating it with demographic attributes. This body of work highlights the importance of integrating diverse datasets to deepen the understanding of migration's socio-economic effects. Nevertheless, the specific impacts of housing prices and age demographics on migration patterns, with a focus on local spatial dynamics, remain insufficiently explored. This paper aims to fill this gap by adopting a visual GIS-based methodology to investigate the local-level spatial relationships between migration flows and housing affordability.

The literature review in this study highlights the profound effects of house prices and age demographics on migration trends, spotlighting the importance of housing affordability, locational preferences, and distance within the housing market. While existing studies have extensively examined the interplay between house prices, age demographics, and migration, there remains a conspicuous gap in the understanding of the spatial dynamics that link migration destinations with the age of migrants and levels of house prices [7,8]. This oversight underscores a critical need for further research into how factors such as age, geographical distance, and housing affordability shape migration patterns across different spatial contexts. This study aims to bridge this gap in the literature on migration research by investigating the spatial relationships between migration flows, demographic age groups, and house prices. Prior investigations have largely concentrated on analyzing migration trends and patterns at broader national and subnational levels, often overlooking the nuanced spatial variations that occur at the local level. By adopting a visual analytical approach and utilizing comprehensive datasets, including census information and house price indices, this paper endeavors to uncover how age and house prices exert influence over migration decisions and patterns at a more detailed geographic scale. This nuanced exploration is intended to contribute valuable insights into the spatial mechanisms of migration, thereby enriching our understanding of the complex interdependencies between demographic factors, economic conditions, and migratory movements.

3. Data

3.1. Geographic Boundaries

In this study, we utilized the geographical demarcations of Output Areas (comprising 8684 areas) and Merged Wards (encompassing 215 areas), as delineated in the 2011 UK Census data, along with the 2011 house price data (covering 25,872 postcodes) obtained from the Land Registry database for the Greater Manchester area.

3.2. Migration Flow Data

Additionally, we utilized migration flow data (as shown in Table 1) sourced from the 2011 UK Census, which was accessible for download at https://wicid.ukdataservice.ac.uk/ (accessed on June 2023). This dataset contained information regarding migration flows from previous areas (one year prior) to current destination areas, aggregated at the levels of output areas and merged wards within Greater Manchester.

Table 1. Mobility flow data at the boundaries of Output Areas.

People Per Flow	Flow Number	Average Distance (Km)	Maximum Distance (Km)	Total People	People Per Flow	Flow Number	Average Distance (Km)	Maximum Distance (Km)	Total People
1	75,634	4.9	48.0	75,634	21	7	1.4	2.7	147
2	29,535	3.8	41.3	59,070	22	4	1.3	2.5	88
3	11,417	3.3	36.5	34,251	23	3	0.3	0.9	69
4	7002	3.1	39.1	28,008	24	7	1.2	3.1	168
5	2596	2.9	35.1	12,980	25	1	0.3	0.3	25
6	1513	2.7	37.5	9078	26	1	0.7	0.7	26
7	441	2.0	32.1	3087	27	10	2.1	16.7	270
8	383	2.3	27.7	3064	29	1	0.3	0.3	29
9	150	1.7	17.0	1350	30	1	0.00	0.00	30
10	124	2.3	14.3	1240	32	2	8.7	17.3	64
11	52	1.2	8.5	572	33	3	1.5	3.2	99
12	75	1.9	13.0	900	34	2	0.6	0.8	68
13	37	1.0	3.5	481	35	3	0.9	2.0	105
14	16	1.0	2.9	224	37	1	0.3	0.3	37
15	20	3.4	31.7	300	39	1	0.5	0.5	39
16	11	1.6	5.5	176	41	1	0.8	0.8	41
17	10	0.7	1.8	170	44	1	1.0	1.0	44
18	8	1.4	3.9	144	52	1	0.5	0.5	52
19	5	0.3	0.6	95	62	1	1.4	1.4	62
20	9	0.7	2.2	180	Total	129,089			232,467

In this paper, we investigate migration data by considering variables including the count of individuals moving from previous locations to current ones, segmented into output and ward areas, alongside the calculated migration distances. Age, classified into five groups from 1–15 years old to 75 years old and above, is used to delve into the correlation between age demographics and migration trends, as well as their influence on housing prices. A statistical analysis is employed to examine the relationships between distance, age, and price. These variables are then visualized on GIS maps to explore spatial connections. By examining how different age groups impact migration distance and the dynamics of the housing market in previous and current areas, the research is intended to offer insights into the interplay among age, migration, and housing market trends.

3.3. House Price Data

We utilized 2011 house price data from the UK Land Registry, focusing on the Greater Manchester area. This dataset included 25,872 property postcodes, which were converted into latitude and longitude coordinates to enable visualization on GIS maps—a process known as geocoding. For this conversion, we employed the Google Maps Geocoding API, ensuring the postcodes were properly formatted and exported into the service. Upon receiving the geocoded output—accurate latitudes and longitudes for each property—we then used QGIS, an open-source geographic information system, to map these locations. This me-

thodical approach allowed us to visually analyze and interpret spatial patterns in housing prices, migration distances, and demographic distributions across Greater Manchester.

Tables 2 and 3 offer a condensed overview of the house price data categorized by administrative boundaries, postcodes, average prices, and property numbers. These tables provide a detailed breakdown of house price data across Greater Manchester, organized by administrative boundaries and postcodes. Each table presents the average house prices and the number of properties within specific postcode areas, offering insights into the housing market trends within these regions.

Table 2. Postcodes, average prices, and property numbers (count) in Greater Manchester.

Manchester			Manchester			Manchester			Salford		
Postcode	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**
M1 1	141,575	10	M40	92,992	119	M9 0	76,954	24	M27	115,642	402
M1 2	162,982	133	M41	173,987	473	M9 4	62,777	66	M28	171,794	437
M1 3	162,983	51	M7 4	69,000	4	M9 5	65,000	11	M29	129,707	269
M1 4	149,075	4	M8 0	101,105	54	M9 6	89,579	41	M3 5	106,720	41
M1 5	181,638	55	M8 4	114,056	68	M9 7	102,435	40	M3 6	118,836	25
M1 6	174,464	14	M8 5	115,241	44	M9 8	95,086	112	M3 7	124,279	39
M1 7	131,028	18	M8 8	94,698	20	SK4	219,435	445	M30	121,864	322
M12	78,478	88	M8 9	82,333	18	SK5	107,917	222	M38	64,931	58
M13	120,666	123	M9 0	76,954	24	WA14	341,833	469	M44	127,684	196
M14	124,578	284	M9 4	62,777	66	WA15	348,080	569	M46	108,017	207
M15	128,792	171	M9 5	65,000	11	**Bolton (South)**			M5 3	106,702	115
M16	150,085	283	M9 6	89,579	41	**Postcode**	**Average price**	**Count**	M5 4	85,830	37
M18	87,035	232	M9 7	102,435	40	BL1	104,000	1	M5 5	86,834	33
M19	123,700	292	M9 8	95,086	112	BL2	99,205	129	M50	151,521	175
M2 4	208,000	2	SK4	219,435	445	BL3	83,892	423	M6 5	78,917	51
M2 7	166,000	1	SK5	107,917	222	BL4	86,943	236	M6 6	68,103	34
M20	226,281	752	WA14	341,833	469	BL5	147,400	10	M6 7	118,426	75
M21	221,683	357	WA15	348,080	569	M26	131,148	33	M6 8	119,168	68
M22	138,187	77	M33	214,529	726	**Leigh**			M7 1	116,888	108
M23	110,530	168	M34	125,018	117	**Postcode**	**Average price**	**Count**	M7 2	122,797	51
M3 1	194,821	14	M4 1	141,435	40	WA3	145,703	181	M7 3	111,047	92
M3 2	238,278	9	M4 4	119,228	37	WN2	106,964	235	M7 4	159,240	64
M3 3	228,278	16	M4 5	153,340	20	WN7	90,666	450	WN7	106,463	50
M3 4	182,601	44	M4 6	136,167	3	**Middleton**			**Wigan**		
M31	95,672	39	M4 7	65,000	2	**Postcode**	**Average price**	**Count**	**Postcode**	**Average price**	**Count**
M32	136,562	267	M40	92,992	119	M24	122,428.25	440	WA3	101,654	30
M33	214,529	726	M41	173,987	473	OL10	121,575	2	WN1	146,540	206
M34	125,018	117	M7 4	69,000	4	**Hyde**			WN2	106,704	179
M4 1	141,435	40	M8 0	101,105	54	**Postcode**	**Average price**	**Count**	WN3	126,853	268
M4 4	119,228	37	M8 4	114,056	68	OL5	124,196	120	WN4	119,294	169
M4 5	153,340	20	M8 5	115,241	44	SK14	133,917	426	WN5	121,836	340
M4 6	136,167	3	M8 8	94,698	20	SK15	128,252	245	WN6	141,388	351
M4 7	65,000	2	M8 9	82,333	18	SK16	118,064	168			

Table 3. Postcode, average price, and property numbers (count) in Greater Manchester.

Bolton (North)			Oldham (West)			Rochdale		
Postcode	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**
BL1	136,005	654	M24	100,333	3	BL9	152,625	20
BL2	121,167	277	M35	115,415	168	M24	126,749	4
BL3	146,268	97	M40	101,457	156	OL10	120,716	285
BL5	136,767	272	OL1	117,241	57	OL11	132,429	328
BL6	168,804	325	OL2	124,927	383	OL12	119,512	295
BL7	182,314	146	OL4	107,444	9	OL15	136,432	160
M46	198,273	11	OL8	85,063	214	OL16	108,508	254
WN2	166,425	1	OL9	113,398	304	OL2	110,000	1
Bury			**Ashton-under-Lyne**			**Stockport**		
Postcode	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**
BL0	145,700	175	M11	98,908	161	M22	109,704	228
BL2	143,967	26	M12	81,336	4	M23	98,915	87
BL8	164,825	449	M34	128,633	390	SK1	96,465	85
BL9	111,755	476	M4 6	156,344	39	SK12	397,500	4
M24	74,364	11	M4 7	137,085	90	SK2	149,062	318
M25	159,103	278	M43	98,697	188	SK3	127,145	343
M26	109,792	266	OL6	101,234	201	SK5	69,934	22
M45	179,369	212	OL7	102,829	125	SK6	185,818	568
M8 4	172,374	4	SK15	160,000	1	SK7	244,312	542
Oldham (East)			**Oldham (East)**			SK8	207,286	684
Postcode	**Average Price**	**Count**	**Postcode**	**Average Price**	**Count**	WA15	173,000	3
OL1	82,222	60	OL4	112,369	360			
OL3	192,018	197	OL8	82,958	12			

4. Method

The investigation focused on analyzing the correlation between migration areas segmented by price levels and various household factors, including age distributions, migration distances, and preferences for housing prices. The aim of this paper is to answer the following question: How do house price levels in migration areas correlate with household characteristics including age, migration distance, and previous areas categorized by house price levels? Additionally, we seek to explore the policy implications and contributions to the literature on migration patterns. The answers derived from the research questions are intended to hold significant importance for policy-makers as they endeavor to develop more sophisticated and efficient strategies to address the complexities associated with household migration. By providing valuable insights into the spatial dynamics of household migration concerning house prices at the local level, this paper is intended to contribute to enriching the global conversation on migration studies.

To test these hypotheses, we performed a cross-tabulation analysis and chi-squared tests to evaluate the relationships between migration distances, age demographics, and housing prices. GIS was used to map and visualize these relationships spatially. The study employed chi-squared tests and spatial mapping techniques to analyze migration flows

and house price data. Chi-squared tests were utilized to assess the association between categorical variables including age, house price, and migration distance. Household ages were segmented into distinct groups, house prices categorized into levels ranging from significantly low to significantly high, and migration flows grouped by distance into short, medium, and long ranges. The null hypothesis stated no significant relationship between these variables. A significance level of 0.05 was chosen to determine statistical significance. Using SPSS software, we calculated the difference between observed and expected frequencies for each category and evaluated the statistical significance of these differences.

On the other hand, spatial mapping involves representing data in geographic space to identify spatial patterns and relationships. To conduct spatial mapping, we utilized QGIS software to present maps of house price data based on latitudes and longitudes, as well as maps of migration flow derived from census flow data. Subsequently, these maps were combined into a single GIS map for spatial analysis. The objective of these maps is to illustrate the spatial patterns of migration flows in relation to factors such as age, migration distance, and house prices.

The UK Census is conducted once every ten years, with the most recent censuses taking place in 2011 and 2021. We utilized census data from 2011, recognizing that there may have been numerous changes in demographic shifts, housing markets, mobility patterns, and economic conditions since then, which could impact the study's findings. While the 2021 Census data became available for download in 2023, the study proceeded with the 2011 dataset as the basis for its initial investigation. However, the availability of the 2021 dataset presents an opportunity to validate the results and explore any changes in spatial patterns and their associations. Looking ahead, there is potential to analyze trends over a 10-year period using the 2021 census data, thereby enhancing the longitudinal perspective of the study.

4.1. Determining Age Ranges

We utilized the 2011 Census data, incorporating age distribution within migration flows, segmented into the following age ranges: 1–15, 16–49, 50–64, 65–74, and 75 and above.

4.2. Determining House Price Levels and Migration Distance Ranges

We applied the k-means clustering algorithm to categorize house prices and migration distances, following the methodologies outlined by Caliński and Harabasz [34] and Hincks et al. [33]. The k-means method is a clustering algorithm that partitions data into K distinct groups based on similarity. It achieves this by initializing K centroids, assigning each data point to the nearest centroid to form clusters, and then iteratively moving the centroids to the average location of the points within each cluster until the positions of the centroids stabilize, indicating that the clusters are as compact and distinct from each other as possible [35].

The principal components of this methodology involved computing the Variance Ratio Criterion (V) and executing the Tukey post hoc test [36], facilitated by the SPSS software suite. The Variance Ratio Criterion (V), often associated with the Caliński–Harabasz index, is a statistical measure used to evaluate the quality of clusters in clustering algorithms like k-means [34]. It is defined as the ratio of the between-cluster variance to the within-cluster variance. A higher Variance Ratio Criterion value indicates better-defined clustering, where data points in the same cluster are more similar to each other (low within-cluster variance) and data points in different clusters are more distinct (high between-cluster variance). On the other hand, the Tukey post hoc test, or Tukey's Honestly Significant Difference (HSD) test, is a statistical method used to identify significant differences between the means of all possible pairs of groups after an ANOVA indicates overall significant differences [36]. It controls for Type I errors across multiple comparisons by comparing the mean differences to a critical value, determining which group means are significantly different from each other. In short, the Tukey post hoc test and the Variance Ratio Criterion serve different purposes in statistical analysis: Tukey's test identifies significant differences between group

means after ANOVA, while the Variance Ratio Criterion assesses cluster quality in methods like k-means by comparing between-cluster and within-cluster variance. Together, they can validate clustering solutions and the significance of differences between clusters.

To conduct the k-means method, we first determined the Variance Ratio Criterion (V) values by deriving F-values through a one-way ANOVA analysis in SPSS software, a statistical method used to compare means across different groups. Second, the value of Q_n, representing the rate of change in V across varying numbers of clusters, was computed using the equation provided below. Third, by assessing the change in Q_n, we selected the optimal cluster solution with the lowest Q_n value, indicating the point of diminishing returns in improving clustering quality. Fourth, the significance of the Tukey post hoc test was considered to validate the chosen classification. Based on the ANOVA analysis to determine the significant differences between groups, we utilized SPSS to conduct the Tukey test via SPSS's 'Compare Means' feature. Finally, we reviewed the output with the comparisons between groups together with significance levels and paid attention to group comparisons with significance levels at or below 0.05, ensuring statistically meaningful distinctions.

$$Q_n = (V_{n+1} - V_n) - (V_n - V_{n-1})$$

4.2.1. Determining House Price Levels

Table 4 displays the Variance Ratio Criterion value (V), Q_n value, Tukey post hoc test results, and the optimal grouping option for house prices.

Table 4. Clusters, Q_n, and Tukey post hoc test for grouping house prices.

Cluster Number (n)	V	Q_n	Tukey HSD *	Optimum Solution **
2	185.52	NA	X	x
3	440.325	−180.341	X	x
4	514.789	−96.2929	X	x
5	492.96	−351.938	ok	ok
6	519.113	297.6617	ok	x
7	842.928	47.9817	X	x
8	814.805	92.88874	ok	x
9	879.571	165.4012	ok	x
10	1109.737	−25.241	X	x
11	1314.663	−259.518	X	x
12	1260.071	562.4933	ok	x
13	1767.972	−28.482	X	x
14	2247.391	−425.589	X	x
15	2301.221	NA	X	x

* 0.05 significance. ** Chosen option with the significant Tukey test result and the minimum value of Q_n.

We opted for a five-cluster model (n = 5) for the analysis. Utilizing the boundaries of 215 merged wards and calculating the average sold price for each area within Greater Manchester, the optimal cluster selection, as determined from the analysis, is outlined in Table 5.

Table 5. Merged wards grouped by five house price levels.

Price Classification	Member Number	Price Level (£)
Significantly low	73 areas	63,445–109,257
Low	79 areas	110,593–151,034
Medium	41 areas	153,395–206,934
High	18 areas	211,629–286,002
Significantly high	4 areas	324,563–627,629
Total	215 areas	

4.2.2. Determining Migration Distance Ranges

Table 6 presents the Variance Ratio Criterion, Q_n value, and Tukey post hoc test results for mobility distance ranges. Based on the analysis, the optimal cluster selection for distance ranges was determined to be four (n = 4), corresponding to the minimum Q_n value and the significance of the Tukey post hoc test for this classification.

Table 6. Classification, the value Q, and the Turkey post hoc test for migration distance ranges.

Classification Number (n)	Variance Ratio Criterion (V)	Value Q_n	Tukey Post Hoc Test *	Best Option **
2	255,743.251	NA	X	x
3	321,777.975	−29,346.4	X	x
4	358,466.284	−29,264.8	Ok	ok
5	365,889.778	−13,198.7	X	x
6	360,114.541	7053.218	Ok	x
7	361,392.522	17,389.98	X	x
8	380,060.486	−12,809.3	Ok	x
9	385,919.140	5829.444	Ok	x
10	397,607.238	8199.269	X	x
11	417,494.606	12,659.74	X	x
12	450,041.709	−9713.2	Ok	x
13	472,875.607	9890.892	X	x
14	505,600.398	−12,326.1	X	x
15	525,999.087	NA	X	x

* 0.05 significance. ** Chosen option with the significant Tukey test result and the minimum value of Q_n.

Table 7 showed the detail for the four distance levels.

Table 7. Four distance classifications.

Distance Level	Member Number (Flow)	Distance Level (Km)
Short	28,712	0–4.27
Medium	8469	4.27–11.19
Long	89,746	11.19–18.09
Significantly long	2162	Over 18.09
Total	129,089	

5. Results

In this section, we initially explore whether individuals' previous locations influenced their subsequent destination areas. Secondly, we investigate whether age demographics influenced households' relocation destinations. Lastly, we delve into the relationship between migration distance and destination areas categorized by price levels.

5.1. The Spatial Relationship between Destination and Origin Areas Based on House Price

Based on the methodology and data outlined previously, we categorized both the original migration areas and the destination migration areas into five distinct house price levels: significantly high price, high price, medium price, low price, and significantly low price in Table 8. Subsequently, a crosstabulation analysis and chi-squared test were performed, with the results depicted in Figure 1 and Table 9.

Table 8. Crosstabulation table for original areas and destination areas.

Crosstabulation Table			Destination Areas					Total
			Significantly High Price	High Price	Medium Price	Low Price	Significantly Low Price	
Original areas	Significantly high price	Count	12	62	66	75	37	252
		Expected Count	3.5	25.1	44.6	92.8	86.0	252.0
		% of Total	0.1%	0.3%	0.4%	0.4%	0.2%	1.4%
	High price	Count	48	270	387	667	482	1854
		Expected Count	25.8	184.5	327.8	682.8	633.1	1854.0
		% of Total	0.3%	1.5%	2.1%	3.7%	2.7%	10.2%
	Medium price	Count	64	384	654	1152	957	3211
		Expected Count	44.6	319.6	567.8	1182.6	1096.4	3211.0
		% of Total	0.4%	2.1%	3.6%	6.4%	5.3%	17.7%
	Low price	Count	81	621	1143	2515	2331	6691
		Expected Count	93.0	665.9	1183.1	2464.3	2284.7	6691.0
		% of Total	0.4%	3.4%	6.3%	13.9%	12.9%	36.9%
	Significantly low price	Count	47	468	957	2271	2386	6129
		Expected Count	85.2	610.0	1083.7	2257.4	2092.8	6129.0
		% of Total	0.3%	2.6%	5.3%	12.5%	13.2%	33.8%
Total		Count	252	1805	3207	6680	6193	18,137
		Expected Count	252.0	1805.0	3207.0	6680.0	6193.0	18,137.0
		% of Total	1.4%	10.0%	17.7%	36.8%	34.1%	100.0%

The table above reveals a pronounced correlation between individuals' prior residences and their subsequent relocation destinations, categorized by house price levels. Notably, there is a substantial percentage of migrations occurring between areas classified as low price and significantly low price (13.9% and 13.2%, respectively). In stark contrast, the migration percentages between significantly high price areas to high price areas, and from significantly high price areas to significantly low price areas, are minimal (0.1% and 0.3% for the former, and 0.2% for the latter, respectively). The bar chart further elucidates the distinct connection between previous migration areas and current destination areas. Despite the overall trend, there are still observable migration linkages from significantly high price areas to significantly low price areas. Predominantly, migration activities are concentrated in areas characterized by significantly low and low prices.

Figure 1 illustrates the price levels in both the original areas and the destination areas, along with the corresponding number of households relocating. It depicts a robust connection between households' prior residences and their current migration destinations, delineated by price levels. Although the majority of migration activities are concentrated in significantly low price areas and low price areas, notable migration linkages persist between significantly high price areas and significantly low price areas.

To ascertain whether individuals' prior residences influenced their selection of migration destination, we conducted the chi-squared test (as shown in Table 8). Table 8 demonstrates a significant association between the price levels of original and destination areas through the chi-squared test, with a notably low significance value of 0.000 (Asymp. Sig), indicating a strong correlation. Essentially, the chi-squared test fundamentally compared observed data to what would be expected if no relationship existed between the variables. The significantly low significance value of 0.000 strongly supported the research question posed above, confirming that the observed relationship between the price levels of original and destination areas was not due to chance, thereby underscoring a significant link between these variables in the study.

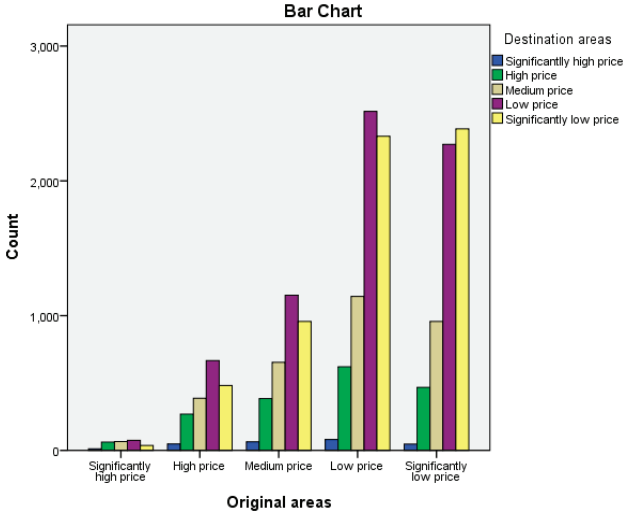


Figure 1. The relationship between original and destination areas based on price levels.

Table 9. Chi-Squared tests for the relationship between original and destination areas based on price levels.

Chi-Squared Test	Value	df	Asymp. Sig. (2-Sided)
Pearson Chi-Squared	389.644	16	0.000
Likelihood Ratio	369.554	16	0.000
Linear-by-Linear Association	355.227	1	0.000
N of Valid Cases	18,137		

Figures 2–5 depict the migration flows into areas categorized by significantly high, high, low, and significantly low house prices. The intensity of these flows is represented through the sizes and colors of the circles on the maps: larger and darker circles signify more substantial migration flows.

Through these visual representations, the study highlights areas experiencing notable migration influxes and traces their origins. Noteworthy migration hotspots include Bowdon and Bramhall in the significantly high price category, Heatons North and St Mary's in the high price category, and Rumworth, Radcliffe West, and Hindley in the significantly low price category, and Broughton and Crumpsall in the low price category.

The findings of this paper underscore the importance of incorporating spatial analysis into migration and housing market research, building upon the foundational [12]. While their research offered significant insights into the relationship between house prices and migration flow at a regional level within UK cities, highlighting key implications for urban policy and planning, it did not delve into the granular details of migration patterns at the local level, such as the specific origins and destinations of migrating households.

In recent years, a body of research has explored the complex interplay between house prices and mobility across various nations, shedding light on how housing affordability influences migration behavior within specific country contexts. Although these studies offer empirical insights into the relationship between housing market dynamics and population movements, they often overlook the spatial patterns of migration and house prices. Spatial analysis is crucial for understanding how migration flows intersect with local housing markets and urban development. By examining spatial patterns, researchers can uncover disparities in housing affordability, identify areas experiencing gentrification or urban decline, and assess the efficacy of policy interventions in different regions. The GIS approach

employed in this paper contributes to the analysis of spatial patterns between migration and house prices, providing a more comprehensive understanding of the intricate dynamics within housing markets and population movements.

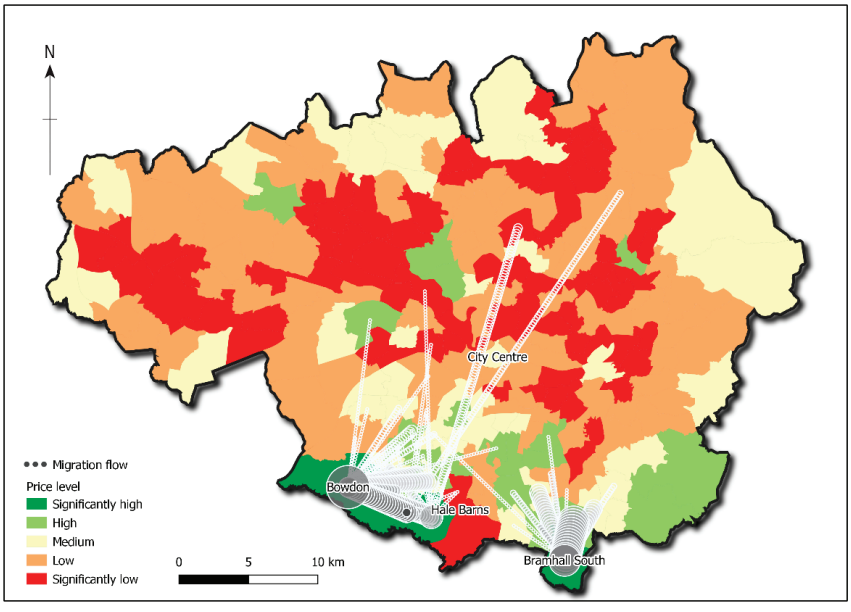


Figure 2. Migration flows entering significantly high price areas.

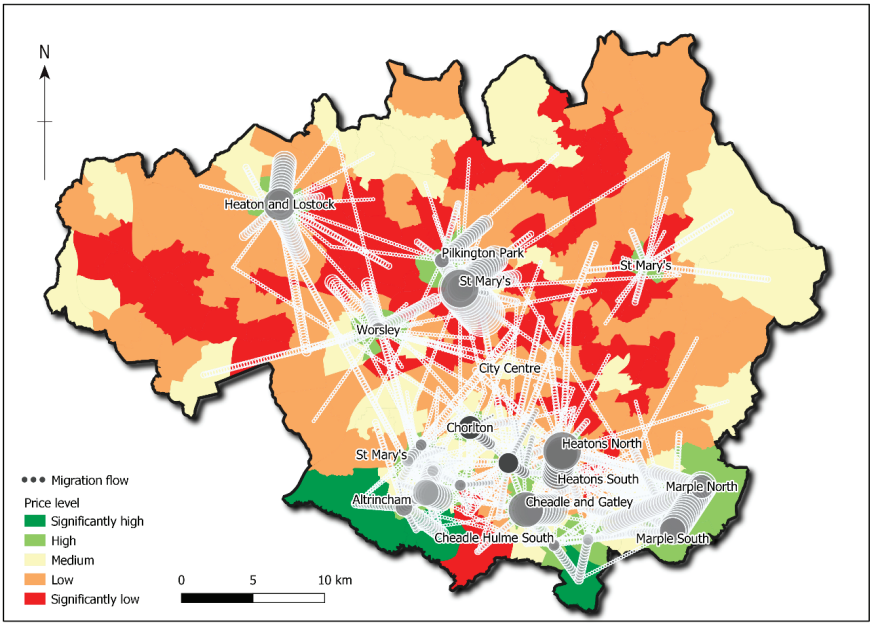


Figure 3. Migration flows entering high price areas.

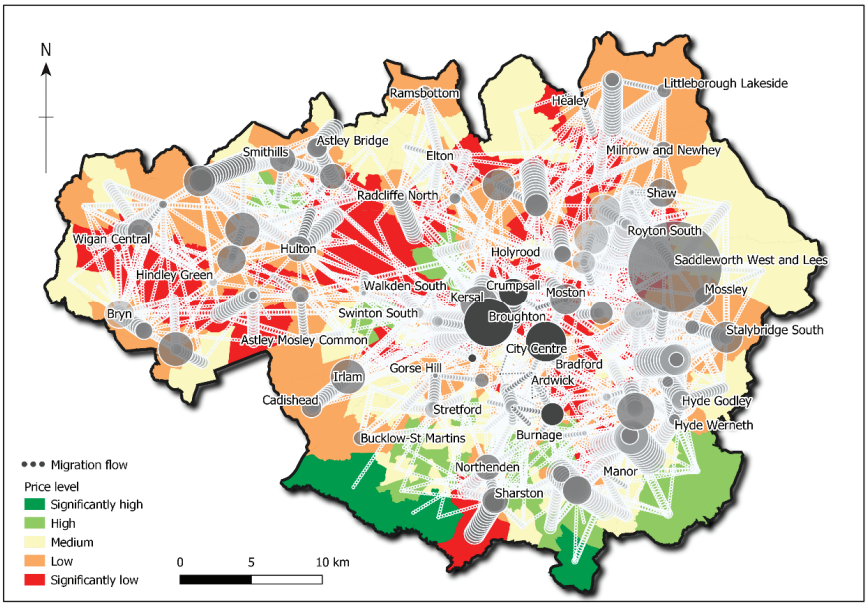


Figure 4. Migration flows entering low price areas.

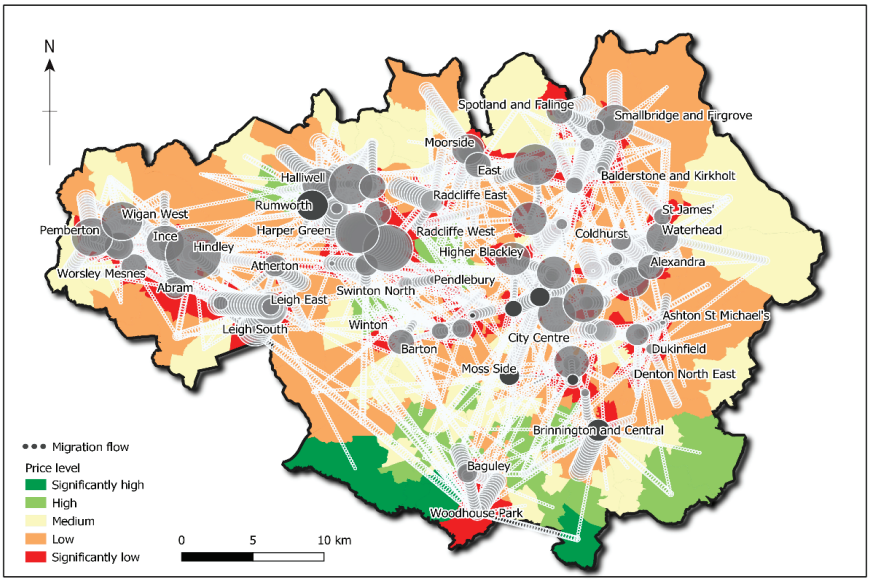


Figure 5. Migration flows entering significantly low price areas.

5.2. The Spatial Relationship between Distance Ranges, House Prices, and Migration

This section delves into the nexus between migration distance and the pricing tiers of migration destinations. Initially, we present a cross-tabulation analysis to explore the correlation between the ranges of migration distance and the levels of house prices (as shown in Table 10). The data reveal a notable trend: a significant proportion of households opt for medium, long, and notably long distances when relocating to areas characterized by significantly low and low house price levels. Conversely, areas classified under the high

price level category register a substantial influx of households migrating over medium distances. This pattern is further elucidated in the accompanying bar chart, visually representing the distribution of migration distances across different house price levels in Figure 6.

Table 10. Cross-tabulation for distance range and price level.

			Price Level					Total
			Significantly High Price	High Price	Medium Price	Low Price	Significantly Low Price	
Distance range	Short distance (below 4.27 KM)	Count	23	270	423	895	869	2480
		Expected Count	34.5	253.5	439.1	914.9	838.1	2480.0
		% of Total	0.1%	1.5%	2.3%	4.9%	4.8%	13.7%
	Medium distance (4.27 KM–11.19 KM)	Count	106	847	1433	3000	2699	8085
		Expected Count	112.3	826.5	1431.4	2982.7	2732.1	8085.0
		% of Total	0.6%	4.7%	7.9%	16.5%	14.9%	44.6%
	Long distance (11.19 KM–18.09 KM)	Count	80	453	793	1721	1705	4752
		Expected Count	66.0	485.8	841.3	1753.1	1605.8	4752.0
		% of Total	0.4%	2.5%	4.4%	9.5%	9.4%	26.2%
	Significanty long distance (Over 18.09 KM)	Count	43	284	562	1075	856	2820
		Expected Count	39.2	288.3	499.3	1040.3	953.0	2820.0
		% of Total	0.2%	1.6%	3.1%	5.9%	4.7%	15.5%
	Total	Count	252	1854	3211	6691	6129	18,137
		Expected Count	252.0	1854.0	3211.0	6691.0	6129.0	18,137.0
		% of Total	1.4%	10.2%	17.7%	36.9%	33.8%	100.0%

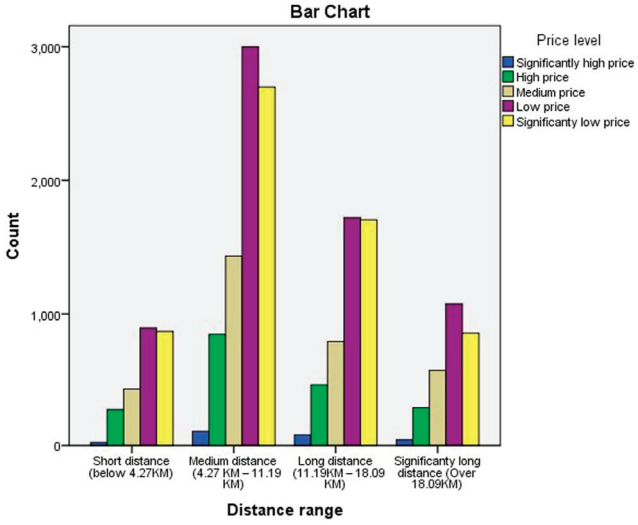


Figure 6. The relationship between distance and migration areas based on price levels.

Table 11 depicted the results of the chi-squared analysis for distance and price level, assessing whether a significant association existed between these two categorical variables by comparing observed data to expected data under the assumption of no relationship. A low significance value (e.g., less than 0.05) typically indicated a meaningful association. The analysis revealed a pronounced association between migration distance levels and the price categories of areas, as evidenced by an Asymptotic Significance (Asymp. Sig) value of 0.000. This statistical evidence addressed the earlier research question, suggesting a marked

propensity for mobility among residents of areas characterized by low and significantly low house prices compared to those residing in high and significantly high-priced regions, indicating that economic factors, notably the cost of housing, played a critical role in influencing household mobility decisions and migration distances.

Table 11. Chi-squared test for distance and price level.

	Value	df	Asymp. Sig. (2-Sided)
Pearson Chi-squared	42.408	12	0.000
Likelihood Ratio	42.714	12	0.000
Linear-by-Linear Association	2.616	1	0.106
N of Valid Cases	18,137		

Figure 7, based on the data regarding distance levels and price-based areas, depicts the spatial distribution of migration flows within the distance range of 4.17 KM and below, categorized by price-based areas, particularly focusing on flows ranging from 150 to 1187 persons per flow. Notably, significant short-distance migrations are concentrated in areas characterized by significantly low house prices, such as Bradford and Charlestown.

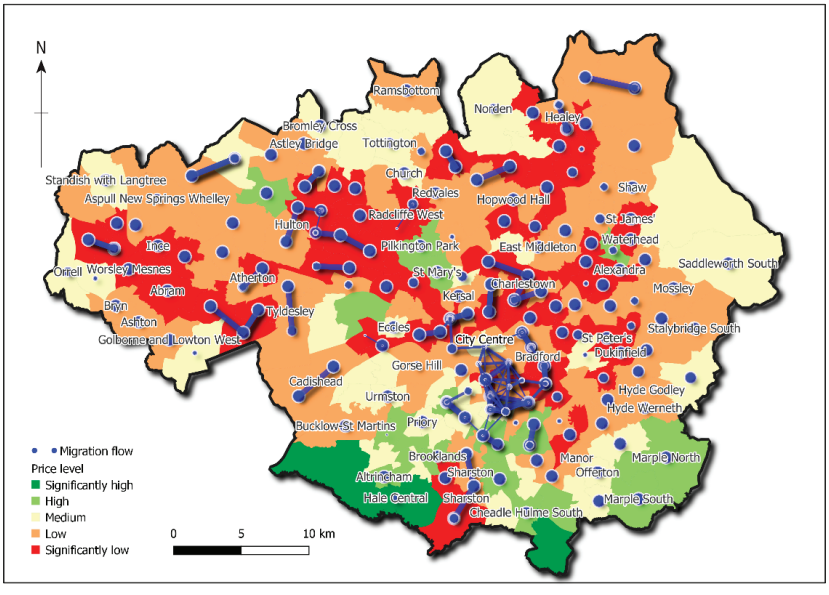


Figure 7. Spatial relationship between distance levels and price-based areas.

Recent research highlights the significant influence of migration patterns, revealing variations in migration distances and motivations across different contexts. Lomax et al. [7] and Darlington-Pollock et al. [11] have explored the patterns of migration distance at national and regional scales, illuminating spatial trends in migration. Despite these insights, the intricate spatial relationships between migration, distance, and housing prices at the local level have received less attention. This oversight suggests a fertile area for investigation into how local migration patterns are shaped by the interplay between distance and housing price dynamics, contributing to a deeper understanding of the spatial nuances of migration. The methodology presented in this paper provides a framework for probing these complex spatial dynamics, offering a novel approach to dissecting the influences of distance and price on migration at a more granular level.

5.3. The Spatial Relationship between Ages, House Prices, and Migration

The analysis delineates a notable correlation between age demographics and housing price levels, with a pronounced inclination of individuals aged 16–49 towards regions characterized by low (26.5%), significantly low (24.9%), and medium (12.7%) housing prices in Table 12. This trend underscores the priorities of this age bracket, possibly driven by budget considerations and life stage needs. Conversely, there is a marked scarcity of migration from all age categories, barring the 16–49 group, into areas with high and significantly high housing costs, indicating potential affordability barriers or differing needs among these groups. Overall, the age group of 16–49 exhibits the highest mobility across various price levels, highlighting their significant role in urban migration patterns.

Table 12. The crosstabulation for ages and price levels.

			Areas Based on Price Levels					Total
			Significantly High Price	High Price	Medium Price	Low Price	Significantly Low Price	
Age	Aged 1–15	Count	478	3140	5424	14,931	19,510	43,483
		Expected Count	444	3593	7291	15,945	16,211	43,483
		% of Total	0.2%	1.4%	2.3%	6.4%	8.4%	18.7%
	Aged 16–49	Count	1472	13,748	29,601	61,692	57,906	164,419
		Expected Count	1677	13,585	27,568	60,292	61,297	164,419
		% of Total	0.6%	5.9%	12.7%	26.5%	24.9%	70.7%
	Aged 50–64	Count	224	1335	2318	5292	5657	14,826
		Expected Count	151	1225	2486	5437	5527	14,826
		% of Total	0.1%	0.6%	1.0%	2.3%	2.4%	6.4%
	Aged 65–74	Count	87	392	723	1485	1570	4257
		Expected Count	43	352	714	1561	1587	4257
		% of Total	0.0%	0.2%	0.3%	0.6%	0.7%	1.8%
	Aged 75 and over	Count	110	592	912	1845	2023	5482
		Expected Count	56	453	919	2010	2044	5482
		% of Total	0.0%	0.3%	0.4%	0.8%	0.9%	2.4%
Total		Count	2371	19,207	38,978	85,245	86,666	232,467
		Expected Count	2371	19,207	38,978	85,245	86,666	232,467
		% of Total	1.0%	8.3%	16.8%	36.7%	37.3%	100.0%

The chi-squared test (as shown in Table 13) was utilized to examine the relationship between different age ranges and housing price levels, with the aim of uncovering whether distinct age groups display varying preferences influenced by economic factors. In this analysis, particularly focusing on the group aged 75 and above, we identified a distinctive and significant correlation, as evidenced by a Pearson chi-squared value of 0.000. Such a low significance level indicates that the observed association is highly unlikely to have occurred by chance, thus providing robust statistical evidence that supports the research hypothesis. This result unequivocally suggests that individuals within this age cohort exhibit deliberate preferences in their migration patterns, which are predominantly influenced by housing price levels. The finding underscores the critical role that economic considerations play in the residential decision-making processes of the elderly population, possibly in conjunction with other factors such as accessibility, community services, and healthcare availability, highlighting how these elements collectively influence the migration decisions of older adults.

Table 13. Chi-squared test for age group and price levels.

	Aged 1–15	Aged 16–49	Aged 50–64	Aged 65–74	Aged 75 and More
Pearson Chi-squared	0.992	0.999	0.852	0.906	0.000
Likelihood Ratio	0.950	0.999	0.920	0.893	0.006
Linear-by-Linear Association	0.000	0.131	0.006	0.759	0.065
N of Valid Cases	18,137	18,137	18,137	18,137	18,137

Figure 8 depicts the migration patterns of individuals aged 75 and above, revealing notable movement trends characterized by short-distance relocations from higher-priced to lower-priced areas, exemplified by flows from locales such as Hyde Godley to Bramhall South. Similarly, substantial migration flows were observed between areas characterized by significantly low housing prices, as evidenced by movements between Harpurhey and Great Lever. These findings illuminate the mobility preferences and tendencies of elderly populations, emphasizing their propensity for relocation to areas offering more affordable housing options and/or potentially better access to essential amenities and services.

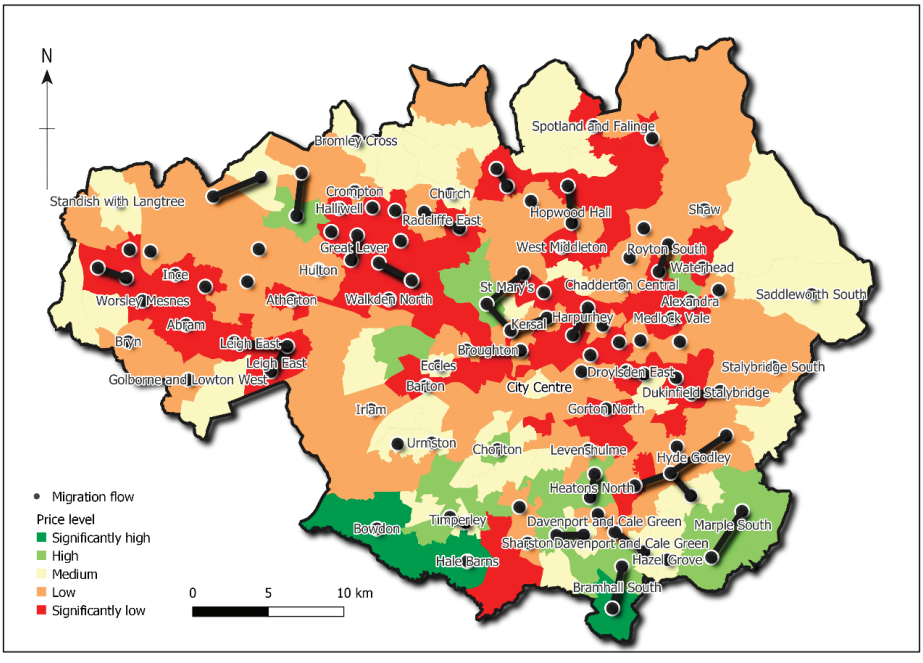


Figure 8. The patterns of moves by people aged 75 and above.

This finding aligns with previous research by Feng and Wang [26] and Levy and Mussida [28], which highlights a robust correlation between migration patterns, mobility distances, and age demographics. Individuals transitioning into retirement age are inclined to undertake longer-distance moves, whereas older retirees often opt for shorter relocations, potentially motivated by factors such as retirement care or downsizing. Moreover, migration trends exhibit significant activity during early adulthood and middle age, with many young and middle-aged individuals relocating for educational, career, or familial reasons [28]. However, prior studies primarily relied on statistical analyses and did not delve into spatial exploration to discern the spatial patterns underlying such migrations.

This paper contributes by offering an effective approach to unravel spatial patterns and identify problematic areas associated with age demographics and house price levels.

In short, the analysis supported Hypothesis 1, showing that higher housing prices are associated with shorter migration distances, highlighting the impact of housing prices on migration distances. However, Hypothesis 2 was only partially supported, revealing that while certain age groups prefer specific housing price ranges, the effect is less pronounced than anticipated. Hypothesis 3 was confirmed, with varying strengths of association observed across different geographic areas. Spatial variations within Greater Manchester affect the relationship between migration and housing prices, emphasizing the need for localized policy interventions.

6. Conclusions and Discussion

In this paper, we examined the correlation between migration areas categorized by house price levels and three household characteristics: age, migration distance, and previous areas grouped by house price levels. Through a cross-tabulation analysis, chi-squared tests, and GIS techniques, significant connections were identified between destination migration areas and house price ranges, in conjunction with household age groups, migration distance ranges, or previous locations associated with specific house price levels. We leveraged the GIS overlay technique to combine multiple spatial data layers, including migration patterns and housing price levels, uncovering new insights into the spatial correlation between migration factors and housing prices. This approach enabled the visualization of complex relationships on maps, highlighting distinct spatial patterns and areas where economic factors significantly influence migration decisions. By providing a clear, visual format, GIS was instrumental in revealing and illustrating the nuanced interplay between migration behaviors and housing prices, thereby enhancing the study's exploration and communication of intricate spatial dynamics.

This study's hypotheses have been instrumental in elucidating the complex relationships between migration patterns, housing prices, and demographic factors. The results underscore the importance of considering these variables in urban planning and policy development, providing suggestions for urban planners and policy makers. These findings suggest that urban planners and policy-makers should consider implementing targeted housing policies that address the specific needs of different age demographics. For instance, the group made up of individuals aged 16–49 played a significant role in urban migration patterns, often moving into areas with high and significantly high housing costs more frequently than other age groups. The affordable housing initiatives in urban centers could attract younger populations, while developing age-friendly communities in suburban areas could better serve older residents. Additionally, enhancing public transportation links between urban and suburban areas could facilitate mobility for all age groups, thereby addressing the disparities in migration patterns related to housing price. The migration patterns of individuals aged 75 and older, which are characterized by short-distance relocations from higher-priced to lower-priced areas, reveal notable movement trends. The interplay of distance, age, and house prices shapes migration trends, with significant implications for local sustainability, highlighting the need for policies that address housing affordability and promote balanced demographic shifts.

Building upon these research findings, we propose the following policy implications and contributions to the literature on migration patterns. Firstly, the employment of a GIS approach in this study revealed its effectiveness in spatially identifying specific migration patterns and problematic migration areas, contingent on the availability of migration flow data and house price data. Such insights enable policy-makers to devise more informed solutions to challenges associated with household migration. For instance, enhancements to property conditions or the construction of new housing in areas of high migration density could be considered, as well as strategies to alter existing migration patterns. In particular, in the analysis above, we identified migration hotspots such as Bowdon, Bramhall, Heatons North, and St. Mary's. The price levels in these areas were

notably higher compared to others. The construction of new houses in these areas may alleviate the affordability problem. Conversely, in areas with the lowest price levels, such as Broughton and Crumpsall, relocation activities were quite high, implying that households were moving out due to dissatisfaction with neighborhood or property conditions. In this case, improving property conditions or neighborhoods may help encourage households to continue residing in such areas.

Secondly, the findings of this paper enrich the international body of research on migration studies by offering insights into the spatial relationship between household migration and house prices at the local level. The study underscores the significance of utilizing a GIS approach to examine the spatial dynamics between household migration determinants and house price levels. It also emphasizes the value of migration flow data and house price data in enhancing our comprehension of the spatial migration behaviors of households. Through these contributions, the paper not only advances academic understanding but also provides practical insights for urban planners, policy-makers, and researchers interested in the intricate dynamics of migration and housing markets. The paper provides evidence of a correlation between migration factors and house price levels in original and destination locations, and highlights the significance of applying a GIS approach. Urban planners can utilize these findings to strategically allocate resources for infrastructure development, housing projects, and community revitalization efforts in migration hotspots, thereby promoting sustainable urban growth. Policy-makers can tailor housing policies and incentives to address affordability issues in high-demand areas while simultaneously implementing measures to improve living conditions in low-priced neighborhoods, thus alleviating relocation pressures and fostering neighborhood stability. Furthermore, researchers can delve deeper into specific factors driving household migration patterns, facilitating the development of targeted interventions and long-term solutions to address real-world challenges related to housing market dynamics and population mobility.

Previous scholarly inquiries have primarily focused on aspects such as migratory intentions, destination preferences, and relocation distances. However, the distinctive contribution of this paper lies in its spatially explicit analysis, which identifies specific migration pathways, spatial distributions, and areas of heightened migratory activity—a facet seemingly underexplored in extant migration research. The salience of this analytical framework lies in its utilization of the GIS methodology, which facilitates identification and targeted intervention in problematic locales and migration hotspots. Consequently, this spatially informed approach holds promise for effective remedial interventions in areas prone to migration-related challenges.

While this study offers valuable insights into the relationship between migration and house prices at the local level, it is important to acknowledge its limitations. Firstly, the paper relies solely on basic statistical and GIS techniques, which may limit the depth of analysis and the generalizability of the findings to other contexts. The use of more advanced analytical methods could potentially yield more robust results applicable to diverse settings. Secondly, while the 2011 migration data are considered outdated and may not fully capture current migration trends due to changes in methodologies and the impact of socio-economic, political, and demographic shifts over the past decade, their use in forecasting or policy-making could result in less reliable outcomes. Nonetheless, this paper is intended to serve as a cornerstone in demonstrating the relationship between migration factors and house prices, proposing a GIS approach to analyze future migration data.

This paper represents an initial exploration of the complex interplay between migration patterns and house prices. With the availability of 2021 migration data alongside 2011 house price data, there is an opportunity to revisit and assess any changes in the relationship between migration and house prices, as well as in their spatial patterns, offering valuable insights into how these dynamics have evolved over time. Furthermore, the observed correlations between migration factors and house price levels in previous and destination areas suggest the feasibility of developing predictive models. These models could incorporate additional factors such as job trends and demographics, utilizing

advanced analytics, like machine learning, for deeper insights. With access to migration data from 2001, 2011, and 2021, time-series analysis can capture the evolving nature of these dynamics, while segmentation by demographic factors allows for tailored predictions. Such predictive models can help to sharpen our understanding of migration patterns and housing economics, aiding policy and urban planning decisions by potentially forecasting the price levels of areas to which households are inclined to move, based on their age and distance, as well as the price level of their current location. In summary, this paper serves as a foundational investigation, demonstrating a significant relationship between household age ranges, migration distance ranges, and house price levels in both original and destination areas. It proposes a pivotal GIS approach to identify spatial patterns among these variables, contributing a method that can be used to analyze the combination of house price and migration data, particularly given their availability every 10 years.

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References

1. Department for Communities and Local Government Household Projections (2008 to 2033) in England. Available online: https://www.gov.uk/government/statistics/household-projections-2008-to-2033-in-england (accessed on 10 July 2024).
2. Stillwell, J.; Lomax, N.; Sander, N. Monitoring and Visualising Sub-National Migration Trends in the United Kingdom. In *Planning Support Systems and Smart Cities*; Geertman, S., Ferreira, J., Goodspeed, R., Stillwell, J., Eds.; Lecture Notes in Geoinformation and Cartography; Springer International Publishing: Cham, Switzerland, 2015; pp. 427–445. ISBN 978-3-319-18367-1.
3. Šantić, D.; Langović, M.; Đorđević, D.Ž. Urban Sustainability Through the Lens of Migration—Case Study: City of Leskovac, Serbia. *Econ. Themes* **2023**, *61*, 105–119. [CrossRef]
4. Diogo, E. "Why Here?"—Pull Factors for the Attraction of Non-EU Immigrants to Rural Areas and Smaller Cities. *Soc. Sci.* **2024**, *13*, 184. [CrossRef]
5. Heugh, K. Mobility, Migration and Sustainability: Re-Figuring Languages in Diversity. *Int. J. Sociol. Lang.* **2013**, *2013*, 5–32. [CrossRef]
6. Gabriel, S.A.; Shack-Marquez, J.; Wascher, W.L. Regional House-Price Dispersion and Interregional Migration. *J. Hous. Econ.* **1992**, *2*, 235–256. [CrossRef]
7. Lomax, N.; Norman, P.; Darlington-Pollock, F. Defining Distance Thresholds for Migration Research. *Popul. Space Place* **2021**, *27*, e2440. [CrossRef]
8. Peng, C.-W.; Tsai, I.-C. The Long-and Short-Run Influences of Housing Prices on Migration. *Cities* **2019**, *93*, 253–262. [CrossRef]
9. Lomax, N. Internal Migration: Census Data as a Gold Standard for Insight and Visualisation. *J. Maps* **2022**, *18*, 543–550. [CrossRef]
10. Kalogirou, S. Examining and Presenting Trends of Internal Migration Flows within England and Wales. *Popul. Space Place* **2005**, *11*, 283–297. [CrossRef]
11. Darlington-Pollock, F.; Lomax, N.; Norman, P. Ethnic Internal Migration: The Importance of Age and Migrant Status. *Geogr. J.* **2019**, *185*, 68–81. [CrossRef]
12. Ferrari, E.; Rae, A. *Local Housing Market Volatility*; Joseph Rowntree Foundation: York, UK, 2011.
13. Rashid, M.F.A. Capabilities of a GIS-Based Multi-Criteria Decision Analysis Approach in Modelling Migration. *GeoJournal* **2019**, *84*, 483–496. [CrossRef]
14. Department for Communities and Local Government Options for the Future of the Household Projection Model: A Final Report. Available online: https://webarchive.nationalarchives.gov.uk/ukgwa/20120919163536/http://www.communities.gov.uk/publications/housing/optionsfuturemodel (accessed on 10 July 2024).
15. Coulter, R.; Van Ham, M. Following People Through Time: An Analysis of Individual Residential Mobility Biographies. *Hous. Stud.* **2013**, *28*, 1037–1055. [CrossRef]
16. Watkins, C.; MCmaster, R. The Behavioural Turn in Housing Economics: Reflections on the Theoretical and Operational Challenges. *Hous. Theory Soc.* **2011**, *28*, 281–287. [CrossRef]

17. Antony, M.M.; Bieling, P.J.; Cox, B.J.; Enns, M.W.; Swinson, R.P. Psychometric Properties of the 42-Item and 21-Item Versions of the Depression Anxiety Stress Scales in Clinical Groups and a Community Sample. *Psychol. Assess.* **1998**, *10*, 176–181. [CrossRef]
18. Green, R.K.; Lee, H. Age, Demographics, and the Demand for Housing, Revisited. *Reg. Sci. Urban Econ.* **2016**, *61*, 86–98. [CrossRef]
19. Levin, E.; Montagnoli, A.; Wright, R.E. Demographic Change and the Housing Market: Evidence from a Comparison of Scotland and England. *Urban Stud.* **2009**, *46*, 27–43. [CrossRef]
20. Takáts, E. Aging and House Prices. *J. Hous. Econ.* **2012**, *21*, 131–141. [CrossRef]
21. Eichholtz, P.; Lindenthal, T. Demographics, Human Capital, and the Demand for Housing. *J. Hous. Econ.* **2014**, *26*, 19–32. [CrossRef]
22. Ohtake, F.; Shintani, M. The Effect of Demographics on the Japanese Housing Market. *Reg. Sci. Urban Econ.* **1996**, *26*, 189–201. [CrossRef]
23. Pitkin, J.R.; Myers, D. The Specification of Demographic Effects on Housing Demand: Avoiding the Age-Cohort Fallacy. *J. Hous. Econ.* **1994**, *3*, 240–250. [CrossRef]
24. Hiller, N.; Lerbs, O. Aging and Urban House Prices. *Reg. Sci. Urban Econ.* **2016**, *60*, 276–291. [CrossRef]
25. Feijten, P.; Mulder, C.H.; Baizán, P. Age Differentiation in the Effect of Household Situation on First-Time Homeownership. *J. Hous. Built Environ.* **2003**, *18*, 233–255. [CrossRef]
26. Feng, Z.; Wang, Z. The Association between Age and Migration Distance among the Older Population in England. *J. Aging Health* **2016**, *28*, 1047–1067.
27. Raymer, J.; Abel, G.J.; Rogers, A.; Wisniowski, A. Projections of the Older Population and Implications for Migration in the European Union. *Popul. Dev. Rev.* **2017**, *43*, 383–409.
28. Levy, H.; Mussida, C. The Impact of Age and Life Cycle on Migration: Evidence from European Countries. *Eur. J. Popul.* **2020**, *36*, 25–49.
29. Bell, M.; Charles-Edwards, E.; Bernard, A.; Ueffing, P. Global Trends in Internal Migration. In *Internal Migration in the Developed World*; Routledge: London, UK, 2017; pp. 76–97.
30. Zeng, S.; Zhang, X.; Wang, X.; Zeng, G. Population Aging, Household Savings and Asset Prices: A Study Based on Urban Commercial Housing Prices. *Sustainability* **2019**, *11*, 3194. [CrossRef]
31. Chen, Y.; Ni, L.; Ospina-Forero, L. Visualising Internal Migration Flows across Local Authorities in England and Wales. *Environ. Plan A* **2021**, *53*, 616–618. [CrossRef]
32. Champion, T.; Shuttleworth, I. Are People Changing Address Less? An Analysis of Migration within England and Wales, 1971-2011, by Distance of Move: Are People Changing Address Less? *Popul. Space Place* **2017**, *23*, e2026. [CrossRef]
33. Hincks, S.; Kingston, R.; Webb, B.; Wong, C. A New Geodemographic Classification of Commuting Flows for England and Wales. *Int. J. Geogr. Inf. Sci.* **2018**, *32*, 663–684. [CrossRef]
34. Calinski, T.; Harabasz, J. A Dendrite Method for Cluster Analysis. *Commun. Stat.* **1974**, *3*, 1–27. [CrossRef]
35. Hartigan, J.A.; Wong, M.A. Algorithm AS 136: A k-Means Clustering Algorithm. *J. R. Stat. Soc. Ser. C (Appl. Stat.)* **1979**, *28*, 100–108. [CrossRef]
36. Tukey, J.W. *Exploratory Data Analysis*; Addison-Wesley Publishing Company: Reading, MA, USA, 1977; Volume 2.

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Return Migration and Reintegration in Serbia: Are All Returnees the Same?

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Abstract: The Republic of Serbia is traditionally a country of emigration, especially since the 1960s. As a result of this emigration, return migration has become an increasingly intensive migratory process in the 21st century. This study aims to examine the factors behind return migration, as well as to explore the characteristics of the reintegration process in Serbia, including the sustainability of return. This paper is based on a survey (N = 172) and interviews (N = 20) conducted with return migrants in Serbia. The research findings point to the diversity of the return migration factors, among which a longing for the country of origin is singled out as the most important. Regarding the reintegration process, this study highlights several differences that are apparent between retired returnees on the one hand and other returnees (students, employed, unemployed) on the other. The results show that the satisfaction with quality of life upon return is higher among older returnees and that the satisfaction with quality of life decreases as the respondents' level of education increases. It is also found that the sustainability of return is connected to the life satisfaction and that respondents who plan to migrate again are the least satisfied with the quality of life compared to those who plan to stay and those who have not decided yet. This paper provides insights into some of the critical elements of the return migration and reintegration process in Serbia. Since return migrants can contribute to sustainable socio-economic development due to their human, social and financial capital, this study may be of relevance to the development of strategies and the implementation of policies in the domain of migration governance.

Keywords: return migration; reintegration; sustainability of return; returnees; Serbia

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1. Introduction

The Republic of Serbia is traditionally a country of emigration. The first period of emigration began in the 1960s, when numerous baby boomers with different demographic and socio-economic backgrounds left the country in order to achieve a better standard of living abroad, particularly in Western European countries. The second period of emigration began in the 1990s due to the unfavorable political and socio-economic situation in the former Yugoslavia. During this period, there was increased emigration of highly educated people, who emigrated not only to Western European countries but also to countries farther afield, such as the USA, Canada and Australia. A third period of emigration has also taken place in the past decade due to the liberalization of migration policies regarding the employment of foreigners in some European Union countries, especially Germany [1–6].

Since every migration flow has a counterflow, these emigration periods conditioned the process of return migration [7]. In the Republic of Serbia, the return migration flows

have increased significantly in the 21st century compared to the previous period [5]. Accordingly, in recent years, return migration has been recognized as an important issue for the overall development of the Republic of Serbia, and it is being included in legislative and strategic documents.

The aim of this paper is to examine the basic characteristics of the return migration process in the Republic of Serbia. An emphasis is placed on identifying the reasons for the return of returnees with different socio-demographic characteristics. Special attention is paid to analyzing the reintegration process—namely, economic and social reintegration. Regarding social reintegration, this paper focuses on the returnees' relationships and connections with household members in Serbia (if any), wider family members and the local population in general. In terms of economic reintegration, this paper analyzes returnees' experiences, opportunities, and limitations in terms of entering the labor market after their arrival in their country of origin. Other challenges faced by returnees in Serbia are also taken into account. An important component of this research is the identification of returnees' intentions regarding secondary emigration, as well as a determination of the factors that influence the sustainability of return migration or motivate the returnees to re-emigrate.

2. Theoretical Background and Literature Review

Return migration is one of the most important components of the migration cycle, beginning from the moment the migrant decides to return to their country of origin [8,9]. The United Nations (UN) defines return migrants as "persons who are returning to their country of citizenship after having been international migrants in another country (both long-term and short-term migration) and who are intended to stay in their own country at least for a period of one year" [10] (p. 94). According to the Organization for Economic Co-operation and Development (OECD), 20–50% of migrants return to their place of origin or emigrate to a third country within five years of arriving in their initial destination [11]. Given the intensity and scope of return migration, it is not surprising that this topic is increasingly being discussed by academics in the 21st century [12].

The complexity of the topic of return migration requires a multidisciplinary research approach grounded in an appropriate theoretical and methodological framework. The basis of the theoretical considerations regarding return migration can be found in the scientific work of the well-known geographer Ernst Georg Ravenstein, who defined the laws of migration, in which every migration flow generates a counterflow [7,13,14].

Return migration can be also analyzed in the framework of the theory of push and pull factors, one of the more well-known theories on migration. Push factors have a clear negative connotation and are usually related to the place of origin and certain external conditions (climate/ecological factors, pandemics etc.) that encourage emigration from a particular area. Pull factors, on the other hand, are characterized by the positive features of the destination country (employment opportunities, family reasons, etc.) [15,16]. In the case of return migration, however, the pull factors are mainly related to the conditions in the country of origin, while the push factors are related to the destination country.

It is important to point out one of the most frequently cited typologies of return migration, as outlined by Cerase [17]. The author categorized the following types of return migration: return of failure (failure to adapt to the destination country), return of conservatism (return after having acquired capital abroad), return of retirement (as the result of the returnee's desire to spend their retirement in their country of origin) and return of innovation (returnees bring into the country of origin new ideas, knowledge and values and act as agents of change) [18,19].

The work of Cassarino is likewise of great importance in defining the theoretical framework of return migration, in which the author in that context highlights the importance of neoclassical economics, the new economics of labor migration, structuralism, transnationalism, and social network theory [18,20]. The theory of neoclassical economics indicates that migration is primarily motivated by differences in income between the places of origin and

destination. In standard neoclassical theory, return migration is seen as the result of failed migration projects, as the migrant has not succeeded in economically and/or socially integrating in the host country [21,22]. In the new economics of labor migration, the migration decision is considered to be a consequence of familial and household strategies. Return migration is seen as the result of successfully achieved goals in the host country [20,23,24]. The structural approach is based on the social, institutional and contextual factors of the returnee's country of origin. It focuses on return migrants' impacts on their societies of origin. This theory considers that the decision to return is affected by situational and structural factors [20,25,26]. Transnationalism explains that returnees prepare for their return and reintegration into their country of origin by visiting their households and sending remittances [20]. Social network theory emphasizes the importance of relationships and connections between people within a particular social network. Since networks consist of different actors, they can also lead to a return to the country of origin [18,27].

In the 21st century, the results of various studies have shown that the process of return migration is highly complex. A number of researchers [28–37] have found that the decision to return is influenced by various factors, such as family reasons, integration problems in the host country (including discrimination), return at the insistence of partners and/or children, etc. Evidence exists to suggest that migrants' return plans can be negotiated in the context of a variety of personal, family and professional considerations [38] but also that migrants are much more likely to return for social reasons and much less likely to do so for educational or employment reasons [39]. In some cases, migrants decide to return when they fail to achieve their migration goals or find it difficult to integrate [40]. This confirms the complexity of the return migration process but also that this process takes place under different conditions and circumstances, both in the host country and in the country of origin.

Theoretical considerations regarding the reintegration process have not been elaborated in detail in the international literature. Certainly, researchers have devoted more and more attention to studying this complex process since the end of the 20th and the beginning of the 21st century. The multidimensional nature of the reintegration process is based on the fact that returnees adapt to different conditions after returning to their country of origin: economic, social, cultural, psychosocial and political. The sustainability of return migration is a direct consequence of the success of the reintegration process itself. Returnees undergo several adjustment phases after arriving in their country of origin, with many facing a variety of challenges. In many cases, an extended period of time may be required to successfully reintegrate. This means that there is a possibility that some returnees will not reintegrate into the community of their country of origin, which, in some cases, will lead to their re-emigration [41–45].

As the reintegration of returnees is an integral part of the migration process, its success depends on the returnees' experiences during emigration, the conditions in the host country/countries during their stay abroad, and the conditions following their return, including satisfaction with the quality of life upon return [46,47]. In addition to individual factors, the sustainability of reintegration is also influenced by contextual macro factors, which are primarily related to the political and socio-economic situation in the country of origin. In this regard, safe and stable socio-economic conditions that include access to resources, an adequate infrastructure, access to education and health systems, and respect for human rights and needs increase the probability of sustainable return migration [48,49]. The sustainability of return migration is realized when returnees remain in their country of origin and do not re-emigrate [50].

Analysis of the reintegration process characteristics shows that a focus is predominantly placed on the issue of economic and social reintegration, while other aspects have not been studied in detail. In a study conducted among returnees in Greece and Albania, Hausmann and Nedelkoska found that returnees are entrepreneurial and about three times more likely to be employed than non-migrants [51]. In contrast, research results from Central and Eastern Europe showed that returnees are unlikely to actively participate in

the labor market after returning to their country of origin, especially in the first year after their return [52].

When it comes to social reintegration, a number of challenges that returnees may face upon return have been identified. Wiesbrock found that many highly qualified returnees in India and China have a low level of social interaction with the local population in the country of origin and that the majority do not maintain close contact with friends or colleagues in their former host countries either [53]. Chobanyan highlighted the issue of accommodation as a major problem in the reintegration process of returnees in Armenia. The results of his research further showed that returnees are not sufficiently informed about employment opportunities and do not consider the fact that legal regulations may well have changed since their initial emigration [54].

In the Republic of Serbia, a growing number of governmental and non-governmental organizations are dealing with return migration issues. At the beginning of the 21st century, certain measures and activities were adopted to encourage the return of migrants and diaspora members. In this context, one bank in Serbia developed housing loans specifically for non-residents, enabling Serbian citizens living abroad to purchase real estate in Serbia. In addition, tax benefits for the employment of returnees, customs benefits for returnees themselves, and the right to compulsory health insurance, regardless of whether the person has acquired a pension in Serbia or abroad, have been introduced [55].

One of the most important documents in the field of return migration is the Economic Migration Strategy of the Republic of Serbia 2021–2027 [56]. This Strategy, among other things, provides an appropriate basis for improving the normative framework in the field of voluntary return migration. Return migration is recognized within the Strategy as one of the mechanisms of the migration process, the proper governance and management of which can impact the overall development of the Republic of Serbia.

Research on return migration in the Republic of Serbia has been present in academic circles since the beginning of the 21st century. Such research has primarily focused on the return of highly qualified returnees and the possibilities of utilizing their human and financial capital [57–61]. Related to this is research that has focused on analyzing the characteristics of the transnational entrepreneurship of returnees [62]. An increasingly studied topic among authors in Serbia is that of the attitudes and intentions of individual diaspora members concerning the return to their country of origin, as well as an identification of the factors that influence their intentions [63,64]. In the wake of the onset of the COVID-19 pandemic, particular attention has been paid to factors affecting the scope and intensity of return migration and the role of the state immediately following the arrival of returnees in their country of origin concerning their future migration plans [65–69]. In recent years, a number of researchers have focused on the process of reintegration of returnees in Serbia [70].

3. Return Migration in Serbia

Various types of migration processes can be observed in the territory of the Republic of Serbia. The characteristics of spatial mobility in Serbia are related to regional and local differences, as well as to differences between urban and rural areas, especially in the context of economic development [71]. The largest concentrations of migrants are located in the capital of Serbia (Belgrade), as well as in the regional centers of Novi Sad and Niš. Data from the 2022 census show that 46.5% of the population in Serbia are migrants [72].

The issue of emigration is one of the most important topics in Serbia. An increase in the volume of emigration in the 1960s is directly related to the liberalization of emigration policy and economic reform, with these conditions influencing the emigration of the population abroad. The main destination countries for migrants from Serbia in 2011 were Austria (22.5%), Germany (17.9%), Switzerland (13.1%), Italy (7.4%) and France (6.5%). The census data show that the cohort of emigrants consists mainly of men (53.4%), people aged 15–64 (80.5%) and predominantly economically active individuals (56.6%) [5,73].

The intensity of return migration in Serbia is related to the dynamics of international migration. Since the more intensive emigration from Serbia began in the 1960s and 1970s, the return migration flows were registered for the first time in the 1981 census. Consequently, return migration has been evidenced in 1991, 2011 and 2022 (the 2022 census data on return migration and emigration have not been published yet). The total number of returnees in Serbia was 63,801 in 1981, 62,843 in 1991, and 234,932 in 2011. The increase in the number of returnees in the observed period should be considered in light of the methodology applied in the census. Namely, in 1981 and 1991, only returnees who worked abroad were recorded. In 2011, the category of returnees included persons who worked abroad before their return but also family members who stayed abroad with them until their return to Serbia, as well as persons who migrated abroad for other reasons [5]. However, the results of the 2011 census showed that almost a third of return migrants (29.7%) returned to Serbia in the period 2001–2011 (Figure 1).

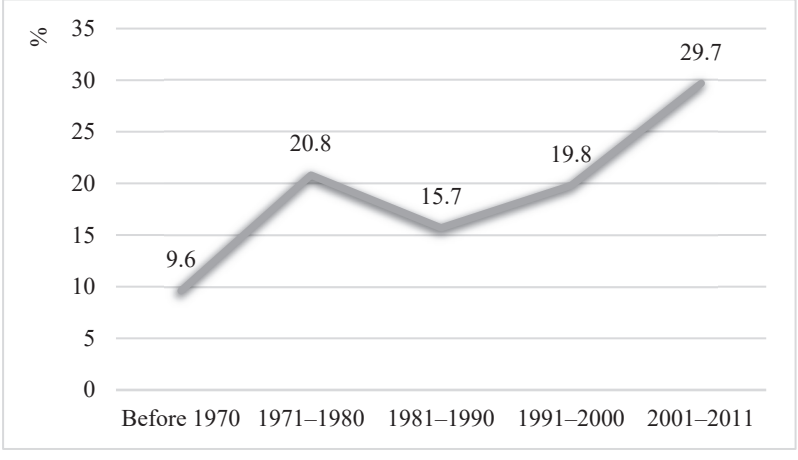


Figure 1. Intensity of return migration flows in Serbia by period of return until 2011. Source: Authors, based on [5].

According to the socio-demographic characteristics of returnees, most of the return migrants in Serbia in 2011 were men (56.9%). More than half of all the returnees (67.7%) belonged to the 15–64 age group, followed by the 65+ age group (30.1%), while young returnees (0–14) made up only 2.2% of the total return migrants. With regard to education, the majority of returnees in Serbia are persons who have completed high school (39.8%). The data on the economic structure show that most returnees (62.9%) are economically inactive [5].

Half of all return migrants in Serbia returned from three EU countries: Germany (26.9%), Austria (14.5%) and France (8.5%). In addition to these countries, Switzerland is also worth mentioning, accounting for 7.4% of all the returnees [5]. Albeit with minor deviations, this shows that the intensity of return migration in Serbia is directly correlated with the dynamics of international migration, i.e., the main destination countries for migrants from Serbia are also those from which most migrants return.

A comparison of the data on the economic activity of emigrants and returnees shows that it is predominantly the economically active population that emigrates from Serbia, with the economically inactive population returning. Considering the fact that 58.7% of the population of Serbia was economically inactive in 2011, it can be concluded that returnees represent the cohort of the population with the largest share of economically inactive persons, both in relation to emigrants and in relation to the total population. If we compare the data on the proportion of highly educated emigrants (15.7%), the total population

(16.3%) and returnees (18.9%) in Serbia, we see that returnees comprise the population category with the largest proportion of highly educated individuals [5,74,75].

The 2011 census demonstrated that the capital city of Serbia (Belgrade) and the regional centers, Novi Sad and Niš, had the highest concentration of returnees. These are the most developed parts of Serbia. Nevertheless, the largest proportion of returnees in the total population of municipalities was predominantly registered in the municipalities in the eastern part of Serbia, such as Žabari (13.6%), Malo Crniće (11.9%), Svilajnac (11.7%), Petrovac (11.1%), Golubac (10.3%), Despotovac (10.2%) and Negotin (9%). These areas are traditionally emigrational, which indicates that migrants from these municipalities prefer to return to their place of origin after a certain period of time abroad. Some municipalities in the southeastern part of Serbia, such as Trgovište (1%), Bosilegrad (1.2%) and Bela Palanka (1.2%), had the lowest proportion of returnees in the total population (Figure 2). These municipalities are characterized by negative demographic and socio-economic challenges—belonging to the group of the smallest municipalities by total population and to the category of least developed municipalities in Serbia. As such, they are not attractive to return migrants.

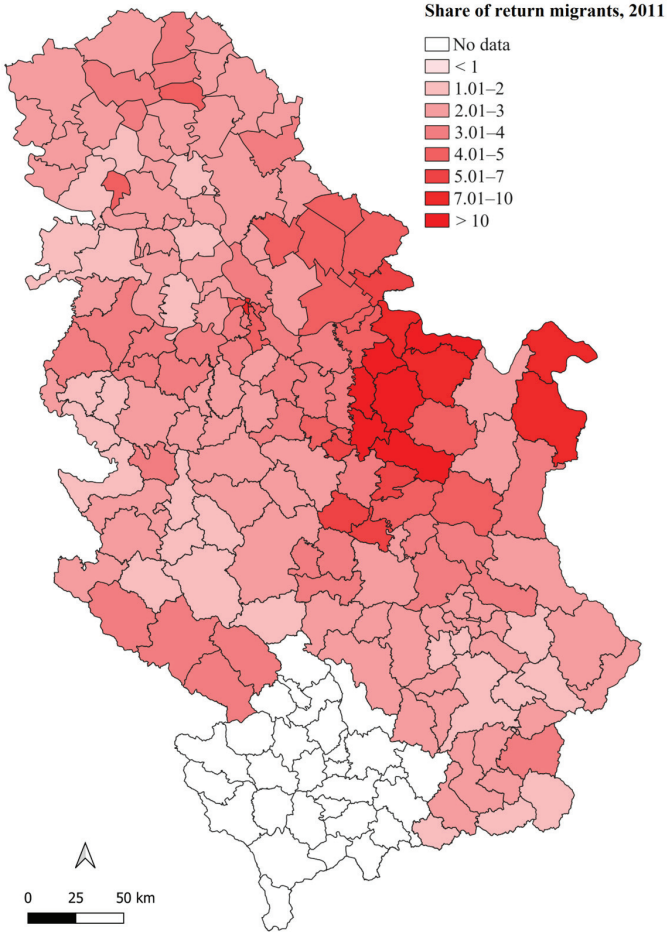


Figure 2. Share of return migrants in Serbia by municipality in 2011. Source: Authors, based on [76].

4. Materials and Methods

The target group of this research are returnees who have returned to Serbia. In this paper, return migrants are defined as persons who have spent at least one year abroad and remained in Serbia for at least six months after their returning. The time frame of the stay abroad formulated in this way allows a certain distinction to be made between circular migrants and return migrants. However, it is important to point out that this time frame does not exclude returnees who were not circular migrants during their lifetime, nor does it mean they will not participate in migration again. On the other hand, a duration of stay in Serbia of six months after return is, in the authors' opinion, significant from the point of view of reintegration process characteristics.

Based on the theories and previous research, the following hypotheses are developed in this article:

- The return migration of respondents is motivated by various reasons, among which familial reasons are the strongest.
- Respondents face challenges in terms of both social and economic reintegration.
- Respondents who are most satisfied with the quality of life in Serbia are least likely to migrate again.

The methodological framework is based on surveys and interviews. The stages of the research process are presented in Figure 3. The survey was conducted in several municipalities in Serbia, and with the mediation of representatives of local municipalities as well as various stakeholders at the local level, and also online in 2023. The online survey was created using Google Forms and distributed to the research target group via e-mail and social networks (Facebook).

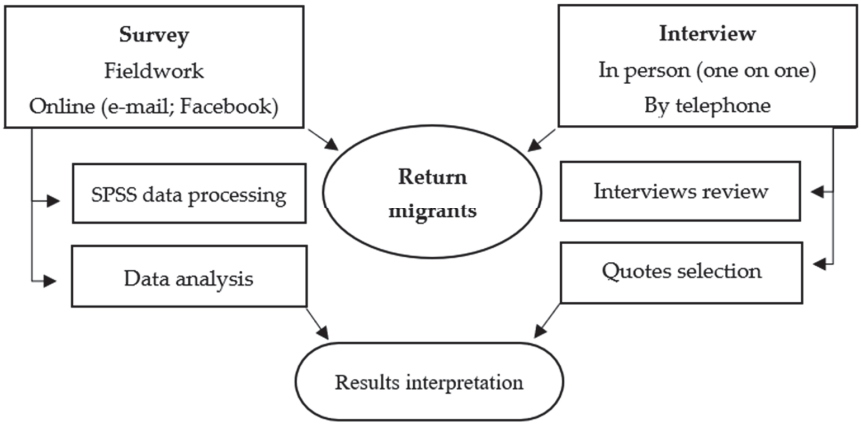


Figure 3. Research process stages.

The questions in the survey were organized into several segments. An emphasis was placed on questions about the reasons for return, reintegration, and secondary emigration intentions. Given the importance of various factors that condition the process of return migration and reintegration, respondents were allowed to choose multiple answers that encapsulated their attitudes and beliefs regarding individual questions within the questionnaire. The following questions are mainly discussed here:

- What are the reasons for your return?
- What kind of difficulties have you encountered in Serbia?
- If you plan to stay in Serbia permanently, what are the reasons for this?
- If you plan to leave Serbia, what are the reasons for a second emigration?
- What conditions must be met for you to stay in Serbia?

The survey data were processed using SPSS Statistics 23.0. First, the basic research questions were processed using descriptive statistics by determining the frequencies and percentages according to the defined categories. Following this, a cross-tabulation statistical method was used to examine the relationship between certain variables. First and foremost, the socio-demographic characteristics of the respondents were cross-tabulated with certain variables to determine the dissimilarities between different categories of returnees in the context of the defined research aims.

Spearman's correlation coefficient was applied in the context of the respondents' life satisfaction after their return and the respondents' age and education. Correlation analysis aims to determine whether there is a quantitative relation between the variations of the observed phenomena. A characteristic of correlation analysis is that the relationship between the variables, if it exists, differs according to the direction and strength. The chi-square test (χ^2) is used to determine the relationship between two categorical variables, each of which may have two or more categories. For the test to be statistically significant, the value of the Sig. must be 0.05 or lower. In this paper, this test was applied to determine a statistically significant difference between the socio-demographic characteristics of the respondents and the challenges in the reintegration process. The Kruskal–Wallis H test was used to determine the differences between the returnees' secondary emigration intentions with regard to their satisfaction with the quality of life in Serbia after their return. It is a non-parametric test and is an alternative to the ANOVA test [77].

In the second part, a semi-structured interview was conducted with the target group of the research; this included a wide range of open-ended questions that allowed an adequate assessment of attitudes and intentions that it was impossible to investigate with a closed questionnaire. In this way, the research findings were supplemented with qualitative data that clarified the process under investigation in many ways. The average length of the interview was 40 min, and interviews were conducted with a total of 20 returnees. Most of the interviews were recorded and transcribed; this made it possible to more easily view, present and analyze the respondents' general and specific views and opinions. The analysis of the interviews is presented through quotes selected to reflect the overall context of the research findings.

5. Results

In the survey, 172 respondents with different socio-demographic characteristics participated. In accordance with the data from the census statistics and the on-the-ground situation, the majority of respondents were men (66.3%), persons who are married (67.4%) and returnees who are retired (50.6%), with a plurality of respondents also being persons aged 65+ (44.1%) (Table 1). Before returning to Serbia, most of the returnees lived in Germany, Austria, Switzerland or France. In addition to these countries, Russia and Slovenia were also important host countries. Most returnees who participated in the study returned in the periods 2011–2019 (41.9%) and 2020–2023 (34.9%).

The common characteristic of all the respondents is that they have lived and/or worked abroad and returned to their country of origin after a certain period of time, while the other elements of their migration process differ to a greater or lesser extent. However, differences were found between the respondents in terms of the factors that motivated them to return to Serbia and their experiences of reintegration. Some returnees did not face any major challenges upon their return to Serbia, while others faced or still face certain problems that interfere with their reintegration. For some respondents, return is the last phase of the migration cycle, while for others, it is another phase of their migration experience.

The results shows that the reasons for the respondents' returns are varied and numerous, and they vary according to the socio-demographic characteristics of the different categories of returnees. During this research, it was found that a single factor or a complex combination of different factors can influence the decision to return. The main reasons for return were a longing for the country of origin (18.3%) and a desire of returnees to spend their retirement in Serbia (16.5%). Return initiated by a partner was also an important factor

of returning (7.6%), as was the possibility of employment in Serbia (7.1%) (Figure 4). However, respondents had the opportunity to indicate more than one factor influencing their return to Serbia. It turned out that among the combinations of factors, the longing for the country of origin and the return initiated by children and/or parents as well as the longing for the country of origin and an insecure job abroad were singled out most frequently.

Table 1. Socio-demographic characteristics of respondents.

	Categories	n	%
Gender	Male	114	66.3
	Female	58	33.7
	Other	/	/
Age	<20	/	/
	20–24	5	2.9
	25–29	9	5.2
	30–34	7	4.1
	35–39	5	2.9
	40–44	11	6.4
	45–49	12	7.0
	50–54	18	10.5
	55–59	12	7.0
	60–64	17	9.9
	65+	76	44.1
Marital status	Single	21	12.2
	Married	116	67.4
	Divorced	12	7.0
	Widowed	22	12.8
	Other	1	0.6
Education	Incomplete elementary school	17	9.9
	Completed elementary school	32	18.6
	Completed high school	85	49.4
	Higher school	10	5.8
	Bachelor degree	21	12.2
	Master degree	6	3.5
	Ph.D.	1	0.6
Activity	Employed	42	24.4
	Seasonal/temporary job	18	10.5
	Student	3	1.7
	Retired	87	50.6
	Unemployed	20	11.6
	Other	2	1.2

Source: Authors, based on research results.

This study shows certain differences in the factors that encourage the return of returnees with different socio-demographic characteristics. For example, the return of women is predominantly initiated by a partner, while the return of men is primarily motivated by a longing for their country of origin and the desire to spend their retirement in Serbia. It was also found that the return migration of younger respondents (younger than 45 years old) is mainly motivated by more than one factor. One of the respondents during the interview highlighted that he decided to return because he has a four-year work contract but also because he realizes that living abroad far away from family and friends is not the life he wants to live. Another one explained that the main factors for his return were longing for the country of origin but also his children and wife, who initiated his return. Some of the highly educated persons returned due to the completion of their education abroad and longing for their country of origin.

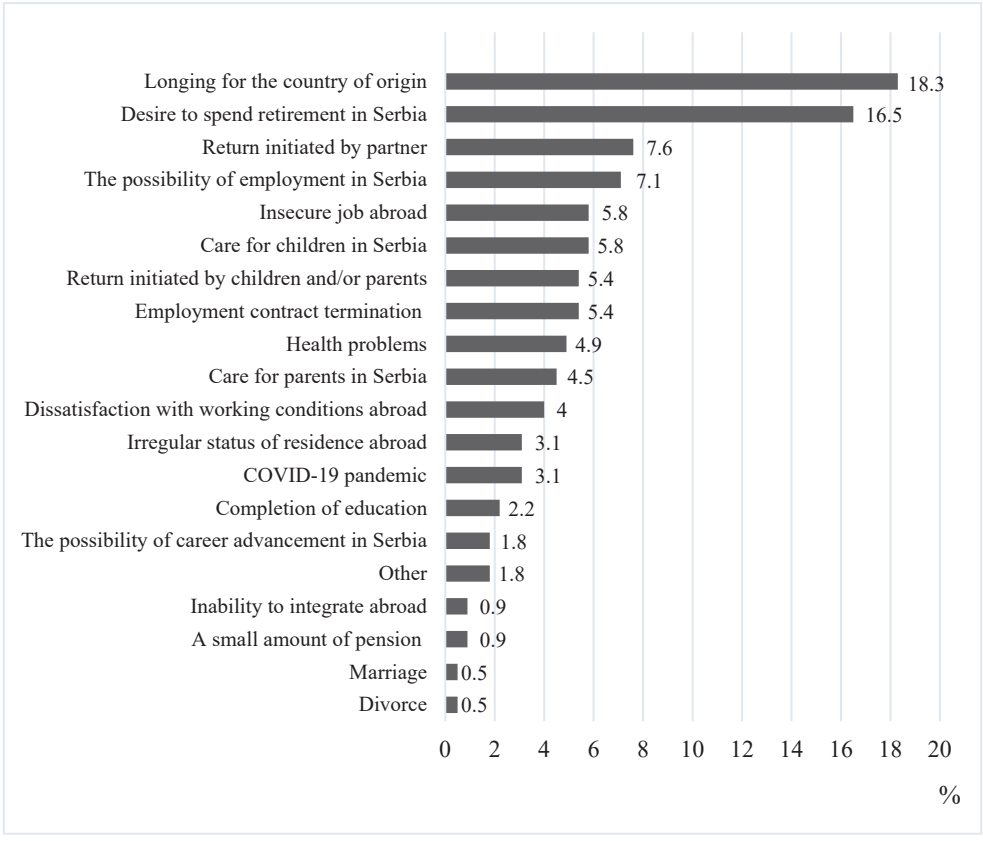


Figure 4. Reasons for return. Source: Authors, based on research results.

The return migration of pensioners—who represent the dominant group of returnees in this study (50.6%)—is primarily motivated by the desire to spend their retirement in Serbia. In addition to this, other important reasons that influence their return are longing for the country of origin and their return being initiated by their partner's desire to return. A number of respondents reflected that their life abroad was a path of challenges and difficulties, and therefore, returning to the country of origin was seen as "the light at the end of the tunnel". Some pensioners explained that they viewed their return to Serbia as a return to a place where they would be able to recover from a busy life abroad.

> *"I wanted to come back sooner, but I kept putting things off because I needed money. When I retired, there were no more excuses. Peace and quiet, my house and drinking coffee in my garden every morning was all I wanted for myself."*
>
> (man, 69)

Although many returnee pensioners expressed satisfaction with certain aspects of their stay abroad, especially their income and/or working conditions, the longing for what they had left behind in Serbia haunted their entire migration journey. Some pensioners returned because their pension could no longer maintain the conditions they had enjoyed during their working life or because their partner decided to move back. Pensioners whose return was motivated by a small pension abroad emphasized that they live very well in Serbia with a foreign pension. Some pensioners noted that their return was initiated by their partner's decision to return, with one partner having a greater desire to return than the other; this was a particularly common reason for return among female retirees.

"My husband had wanted us to return from abroad for a long time. He missed Serbia. I was more in favor of staying with our children and grandchildren in Switzerland. He was persistent that we return together."

(woman, 71)

Immediately after arrival in Serbia, the returnees began a new stage of their migration journey: reintegration. Satisfaction with life in Serbia can be seen as one of the most important prerequisites for the quality of life of the respondents in the place of return. In this regard, on a scale from 1 (least satisfied) to 5 (completely satisfied), the respondents most commonly rated their satisfaction with life in Serbia as a 4 (42.4%). The research results do, however, indicate certain differences between the respondents regarding their life satisfaction in Serbia. The application of Spearman's correlation coefficient revealed differences between the returnees in terms of age and education regarding their satisfaction with the quality of life after return. In both cases, it was found that there is a correlation between the given variables (satisfaction with quality of life and age: $p < 0.001$; satisfaction with quality of life and education: $p = 0.002$). When looking at the correlation between the variables age and satisfaction with the quality of life after return, a correlation coefficient of rho = 0.357 was determined, indicating a positive correlation; i.e., the older the returnees are, the higher their satisfaction with the quality of life. The correlation coefficient between the variables education and satisfaction with the quality of life after return has a negative value of rho = −0.232, which indicates that satisfaction with the quality of life decreases with an increase in the respondents' level of education (Table 2).

Table 2. Spearman's correlation coefficient results.

Variables	Sig. (2-Tailed)	Correlation Coefficient (rho)
Satisfaction with quality of life after return Age	<0.001	=0.357
Satisfaction with quality of life after return Education	=0.002	=−0.232

Source: Authors, based on research results.

The results show that more than 90% of respondents feel accepted by the local population after returning to Serbia. Many of them stated that they had participated in transnational activities during their stay abroad, such as frequent contact with family, friends and relatives, and that they had visited their country of origin frequently. Therefore, upon return, most respondents resumed close ties with their friends and explained that the fact that they lived in different countries for a period of their lives did not terminate their relationship. Besides the local population, returnees often socialize and make friends with other returnees. This study has shown that returnees in rural areas are particularly social compared to returnees returning to urban areas, whose level of socialization is somewhat lower. An interview with some pensioners found that the degree of socialization depends on their state of health. This was particularly observed in some respondents over 75 years old and who were therefore limited to some extent when socializing with others.

The social aspect of reintegration is also evidenced through the respondents' participation and interest in certain social events and activities. Most returnees are familiar with social events in the country. Although the frequency of visits varies, most respondents frequently or occasionally attend cultural and sporting events, as well as religious objects (Table 3). It has been established that people from urban areas mainly attend sporting and cultural events. Visiting religious objects is common among people from both rural and urban parts. Some interviewees stated that they also visited religious buildings during their stay abroad and felt connected to their country of origin in this way. It is evident that they continued this practice after their return.

Table 3. Frequency of participation in certain activities (%).

	Often	Periodically	Never
Cultural events	15.1	58.7	26.2
Sporting events	17.4	44.8	37.8
Religious objects	33.1	53.5	13.4

Source: Authors, based on research results.

In contrast to participation in the activities mentioned above, returnees are less interested in membership of one of the returnees' associations, cultural organizations, or political parties (Table 4). Some cited the lack of desire and time for activities of this kind, which also require a corresponding level of commitment, as the reason for this. One of the interviewees explained that he did not want to get involved in politics because he believed his efforts would not contribute to any change. Pensioners in particular are not interested in joining political parties. However, during the interview, it was noted that many of them vote in elections. A number of interviewees expressed that they would like to become involved in returnees' associations, but they were unaware of the existence of such.

Table 4. Membership of certain associations and organizations (%).

	Yes	No
Returnee associations	1.2	98.8
Cultural organizations	3.5	96.5
Political parties	8.7	91.3

Source: Authors, based on research results.

When it comes to challenges in the process of reintegration, the results showed that the majority of respondents (62.8%) have faced some kind of difficulties, while 37.2% cited that they have not faced any difficulties upon return to Serbia. Most respondents struggle with the difficulties of an inadequate healthcare system (15.1%). It was found that the most common reasons for the dissatisfaction of respondents are the long waiting lists, the lack of necessary equipment in healthcare facilities, inadequately equipped clinics or poor work organization in healthcare centers.

Integration into the labor market is one of the most important prerequisites for successful reintegration in the country of origin regarding the working population. The results show that 34.9% of respondents are permanently employed or have temporary/occasional jobs. However, the post-return labor market opportunities were not particularly favorable for many. Some pointed out that they could not find a suitable job for an extended period of time after their return. Many expressed dissatisfaction with an income that does not cover the cost of living. A low income can also be seen to be one of the main challenges when it comes to the reintegration process of returnees (Figure 5).

It was also found that the economic reintegration challenges often impact other aspects of life. One of the interviewees stated that he and his wife had no plans to expand their family due to their low income and job insecurity. Dissatisfaction with working conditions upon return was one of the challenges faced by individuals, mostly women. It was found that women were generally more satisfied with the working conditions during their stay abroad than in Serbia. Some highlighted that employers abroad appreciated their work more and that they were adequately remunerated, even if the work was not always easy. Some further pointed out that although the work in Serbia is just as difficult as abroad, it is not adequately remunerated. Furthermore, some of the respondents working in the private sector mentioned the attitude of supervisors toward employees as one of the biggest challenges they face in the process of reintegration.

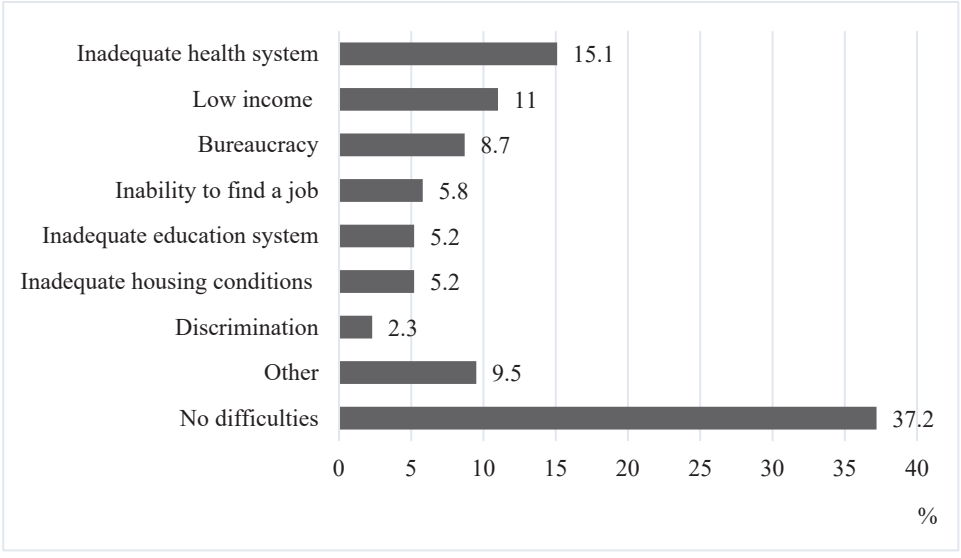


Figure 5. Difficulties in the reintegration process. Source: Authors, based on research results.

The challenges in the reintegration process were also analyzed with regard to the socio-demographic characteristics of the respondents. For this purpose, the groupings of socio-demographic characteristics were reorganized. In relation to the difficulties in the reintegration process, all the respondents were divided into two groups: those who have difficulties and those who do not. The results show that respondents aged 65 years and above (55.3%), respondents with incomplete/completed elementary school (55.1%) and those who are economically inactive (56.7%) predominantly encounter no difficulties in the reintegration process. On the other hand, respondents aged 20–65 were the most likely to experience difficulties (76.7%), as well as respondents with tertiary education (81.1%), respondents who had completed high school (64.3%) and economically active returnees (83.8%). With regard to the gender structure of the respondents, it can be seen that the proportion of those experiencing difficulties is higher in the female sample (71.9) than in the male population (57.5%) (Table 5).

Table 5. Socio-demographic characteristics of respondents and reintegration process (no) difficulties (%).

	Categories	**No Difficulties**	**Difficulties**
Gender	Male	42.5	57.5
	Female	28.1	71.9
Age	20–64	23.4	76.6
	65+	55.3	44.7
Education (respondents who chose the option other in terms of economic activity were excluded from further analysis)	Incomplete/complete elementary school	55.1	44.9
	Completed high school	35.7	64.3
	Tertiary education	18.9	81.1
Activity	Active	16.3	83.8
	Inactive	56.7	43.3

Source: Authors, based on research results.

The chi-square test shows a statistically significant difference between the respondents regarding almost all the socio-demographic characteristics and the difficulties in the reintegration process. This result is primarily based on the data of the significance value, which is less than 0.05 for the variables of age, education and activity, with the value of the χ^2 being highest in the area of economic activity, $\chi^2 = 27.77$. On the other hand, no statistically significant difference was found in relation to the gender structure of the respondents and the difficulties in the reintegration process ($p = 0.067$) (Table 6).

Table 6. Chi-square (χ^2) results.

Socio-Demographic Characteristics/Reintegration Difficulties	Asympt. Sig (2-Sided)	Continuity Correction/χ^2
Gender	=0.067	=2.76
Age	=0.000	=16.83
Education	=0.002	=12.02
Activity	=0.000	=27.77

Source: Authors, based on research results.

Regarding secondary emigration intentions, the results show that the majority of respondents (68%) plan to stay in their place of origin for the rest of their lives. On the other hand, 8.2% of returnees stated that they plan to migrate abroad, while 23.8% have not decided yet (Figure 6). The survey showed that all the respondents over 60 plan to stay in Serbia, with those with incomplete elementary school and those who have completed elementary school being the most likely to stay in Serbia. Certain respondents who have spent an extended period of time abroad (i.e., over 20 years) are also less inclined to move again.

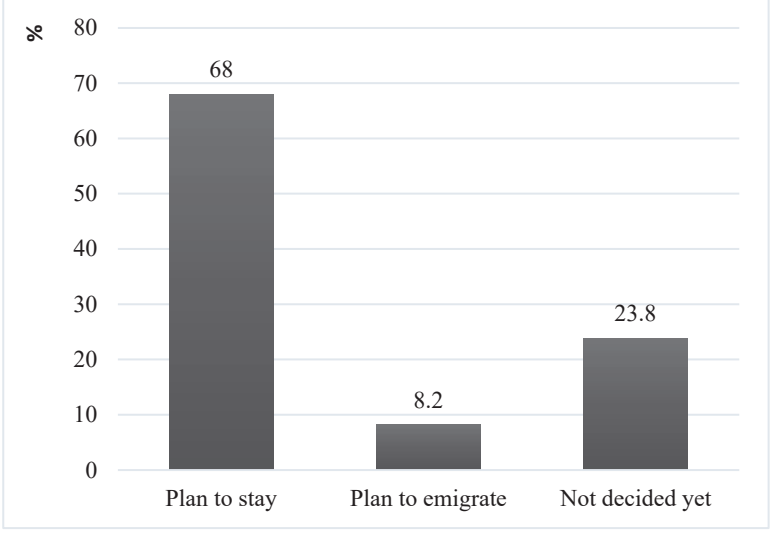


Figure 6. Secondary emigration intentions of respondents. Source: Authors, based on research results.

> *"It's not ideal abroad either. You can earn more and have more. But I have children and a wife in Serbia. I can't even work as hard as I used to. . . 22 years is a long period of time. . . That is why I will not migrate again."*
>
> (man, 57)

The results show that respondents aged 20–24 and 35–39 are mostly likely to migrate, as well as highly educated persons. Returnees aged 30–34 and 45–54 are the most undecided regarding a second emigration. Women are more willing than men to emigrate again. On the other hand, a combination of the following reasons stands out as the main factor for emigrating again: the inability to find a job in Serbia, the possibility of employment abroad, and the desire for a new experience.

> *"At the moment, I don't know what could keep me here. The situation in the country is bad in every way. . . Should a person live on the margins of society?"*
>
> (woman, 37)

The Kruskal–Wallis H test results show a significant difference ($p = 0.000$) between the groups of respondents who plan to stay, plan to emigrate and are not decided yet regarding their satisfaction with the quality of life upon return ($\chi^2 = 23.58$). It was found that the mean results have a greater value in the group of respondents who plan to stay in Serbia (M = 4.22) compared to those who have not decided yet (M = 3.49) and those who plan to emigrate (M = 3.00) (Table 7). In other words, those who plan to stay are the most satisfied with the quality of life after their return, while the respondents who plan to migrate again are the least satisfied with the quality of life in the country of origin.

Table 7. Kruskal–Wallis H test results.

Secondary Emigration Intention/Satisfaction with Quality of Life upon Return	N	Mean (M)	Std. Deviation	Asymp. Sig	df	Kruskal–Wallis H
Plan to stay	116	4.22	0.708	=0.000	2	23.58
Plan to emigrate	14	3.00	1.038			
Not decided yet	41	3.49	1.306			
In total	171	3.94	0.998			

Source: Authors, based on research results.

An important prerequisite for elaborating measures aimed at the sustainability of return migration is the definition of conditions by the respondents that should be fulfilled for them to stay in Serbia. First of all, one cohort of returnees stated that several conditions must be met for them to stay in Serbia permanently—namely, this involves a combination of factors that include the possibility of employment, career advancement, a better standard of living, improvement of the economic situation, and the possibility of higher earnings, with 24.4% of respondents mentioning all four of these factors as playing a role. An improvement in living standards was mentioned by 11% of respondents. It was also found that highly educated persons were more inclined to mention improvements in the field of higher earning potential and career advancement opportunities as some of the conditions that must be achieved in order for them to stay in Serbia permanently. Persons with incomplete primary education mostly stated that they intend to stay in Serbia regardless of the conditions.

6. Discussion

This study can be viewed through the prism of three defined areas of research according to the aims of the paper, relating to (1) the factors of return, (2) the study of the process of social and economic reintegration, and (3) the identification of returnees' intentions about secondary emigration and the factors that influence them, that is, a characteristic of the sustainability of return migration.

The results confirmed the hypothesis that returnees are a heterogeneous category of individuals with different needs and whose migration and post-migration paths can vary widely according to their different socio-demographic characteristics and depend on various factors, including the time spent abroad, time spent in Serbia after return, etc.

The results of this research are consistent with findings [28–40] that the factors influencing return are complex and are, in turn, influenced by a variety of social and economic pull and push factors. In addition, the findings of this research are consistent with certain work [32], which implies that the factors influencing return are increasingly a matter of personal choice, as supported by the fact that the majority of respondents returned either out of a longing for their country of origin or a desire to spend their retirement in Serbia.

However, it is important to note that the family reasons in this research were categorized into six return migration factors (return initiated by partner, return initiated by children and/or parents; care for children in Serbia; care for parents; marriage; divorce). In this sense, it can be concluded that in total, almost a quarter of respondents returned to Serbia for family reasons (24.3%). Therefore, Hypothesis 1: *The return migration of respondents is motivated by various reasons, among which familial reasons are the strongest* is accepted. However, as the research shows that the category of family reasons is extremely broad, it is necessary for researchers to place a greater focus on the analysis of this in more detail in future studies in order to create a more comprehensive image of the return migration factors.

Considering the various factors that influence return migration, reintegration and the sustainability of return, one can conclude that it is not easy to formulate the process of return migration within the framework of a single theory. As the results of this research have shown, it is very important for future studies to consider more socio-demographic characteristics of returnees in order to better understand this process.

The determinants of return may be highly relevant to the formulation of policies that encourage diaspora members to return to their country of origin. The fact that some recent returnees have chosen to return because of employment opportunities in Serbia indicates that perhaps a solution should be precisely sought through employment opportunities that provide adequate compensation for returnees by creating conditions for their work in Serbia and opportunities for career advancement in their country of origin. Undoubtedly, increasing capacities for the creation of improved opportunities in the labor market for this category of migrants is one of the basic mechanisms by which the state can advantageously manage return migration. Since return migrants bring to the country of origin knowledge, skills and experiences [78], the sustainability of return migration is important in the context of the sustainable demographic and socioeconomic development of Serbia.

Although Serbia has recognized the importance of the return migration process, it is necessary that the strengthening of institutional capacities at the state level goes hand-in-hand with the strengthening of capacities at the local level. Educating employers about the needs of returnees and the potentials of their contributions would be an important step in the process of proper management of return migration at all the territorial levels of the country. Registration and mapping of returnees would form a basis for all the activities in the field of appropriate management, which could facilitate further steps of mutual cooperation and mutual benefit [79].

The results show that there are considerable differences between social and economic reintegration. As far as social reintegration is concerned, returnees do not usually face any major difficulties. On the contrary, the social life in Serbia of most is relatively fulfilling, with most feeling accepted by the local population and many being likewise involved in various social activities. On the other hand, the economic aspect of reintegration requires special attention and systemic changes, as some returnees reported an inability to find work and dissatisfaction with their income, with this opinion being especially prevalent among the cohort aged 30–39. When discussing the difficulties they had faced after (re-)arrival in their country of origin, the interviewees primarily referred to challenges in terms of healthcare. In this respect, Hypothesis 2: *Respondents face challenges in both social and economic reintegration* is partially accepted.

It is important to point out that the results presented here indicate differences in the post-migration experience between returning pensioners on the one hand and younger returnees on the other.

The first category mainly includes people who emigrated in the 1960s and 1970s. These are returnees who have spent all or a large part of their working life abroad. Returning pensioners are much more satisfied with the living conditions in Serbia and have no intention of moving abroad again; the majority of them have spent more than a decade abroad, acquired a certain amount of financial capital, and have pensions (mostly foreign) that enable them to lead a more carefree life in Serbia. These returnees usually have no desire to participate in the establishment of a business or to deal with issues relevant to the development of local self-government. Mostly, they invest in the reconstruction of their house/property and/or in cases where their family members live in Serbia, they are very willing to help them financially.

The second category of returnees includes persons who emigrated later, mainly in the 1980s and 1990s or at the beginning of the 21st century. The factors that led to the return of this category of migrants are more diverse than for the respondents in the first group. In most cases, their return is motivated by several different factors. Certainly, numerous pull and push factors, such as the care for children in Serbia, return initiated by children and/or parents, and employment contract termination, were mentioned as important factors for the return of this category of respondents. Longing for the homeland occupies a special place, and it is usually relevant in combination with other factors mentioned. Returnees from this category often face some of challenges in the process of reintegration. The most common challenges of economic reintegration are related to the inability to find a job or dissatisfaction with working conditions/income. These individuals are less likely to participate in solving problems in their community. At the same time, they are more likely to plan to go abroad again, especially highly educated individuals, while many are undecided about whether to remain or not. However, even among this category of returnees, a distinction should be made between certain categories, especially in terms of the educational profile and economic activity. It is clear that in these circumstances, appropriate measures should be taken to meet their needs in the reintegration process.

It is therefore important that the state recognizes these problems among returnees and works on establishing reintegration support and assistance measures that facilitate returnees' adequate access to services in the areas of employment (providing assistance to returnees to find job or start their own businesses), education (providing assistance to those who cannot afford education), counseling (providing helpful information on various aspects of return and reintegration), etc. [80]. As it is the role of the state to receive returnees and help them reintegrate, in certain cases, governments must develop (new) programs to make the reintegration process of returnees as successful and simple as possible [81]. As research has revealed, certain differences exist between returnees in terms of their reintegration, and it is clear that policymakers should take into account such differences between returnees in terms of their gender, age, intention to stay permanently in the country of origin, acquired skills, etc., when formulating reintegration measures [82].

Considering that some respondents declared their intention to migrate again, the research confirms that this type of migration can be of a temporary nature. However, the research likewise indicates that satisfaction with quality of life after return is extremely important for the process of sustainable return migration, thus confirming Hypothesis 3: *Respondents who are most satisfied with quality of life in Serbia are the least likely to migrate again*. Accordingly, it is very important to examine the elements of returnees' quality of life that can be improved in further research and to pay special attention to this with policy measures, as it is obvious that this is how sustainable return migration can be realized. Working to create and strengthen the conditions that influence the sustainability of return migration should be an integral part of the return migration management policy, assuming that the goal of the country of origin is to retain its population that has returned from abroad.

7. Conclusions

Population migration, as a process that directly impacts the country's demographic and socio-economic development, is an issue of national importance in Serbia. Return migration is one of the main migration processes in the Republic of Serbia in the 21st century. The policy of the Republic of Serbia in the field of return migration governance aims to establish and maintain cooperation with the diaspora and encourage return migration. However, research on this topic has not yet been conducted comprehensively in Serbia, especially concerning the reintegration of returnees, i.e., the characteristics of their participation in the socio-economic spheres in their country of origin. Therefore, a question arises not only about how familiar policymakers are with the returnee population and their reintegration but also how well-informed returnees are about their rights and the assistance that Serbia as a country of origin can offer them.

Return migrants in countries that, like Serbia, face unfavorable demographic characteristics can represent a significant population potential and a factor in changing the existing demographic situation. Census data show that most men returning to Serbia are those with a high school degree and those who are not entering employment upon their return. Regarding the age structure, the 65+ age group stands out, accounting for almost a third of all returnees. Under these conditions, return migration can be viewed in terms of increasing the overall population. However, it is clear that the total contribution of return migrants to demographic development would only be achieved if young and fertile people were to participate in return migration to a greater extent. Accordingly, return policies should consider the socio-demographic characteristics of these individuals and emphasize encouraging young migrants to return, while simultaneously working to create conditions within the state that promote and sustain return.

This paper provides a basic insight into the process of return migration and the process of reintegration itself. It represents one of the first research efforts in Serbia on the topic of reintegration, thus providing much room for a more detailed study of this topic in the coming period. Future research should also go a step further and investigate the background of the process of return migration, i.e., determine the influence of other elements of the migration cycle (emigration and immigration) on the process of return migration. Identifying the relationship between emigration factors and the process of integration in the host country with regard to return migration can shed light on new dimensions of this process. Likewise, it is important to point out the need to conduct research in Serbia that includes a larger sample of young returnees and places a greater focus on their reintegration process, which would significantly contribute to the development of the literature in this field of study.

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References

1. Šantić, D.; Langović, M.; Đorđević, D. Urban sustainability through the lens of migration-Case study: City of Leskovac, Serbia. *Econ. Themes* **2023**, *61*, 105–119. [CrossRef]
2. Arandarenko, M. Migracije, kvaalifikacije i tržište rada. In *Ljudski Razvoj Kao Odgovor Na Demografske Promene*; Vuković, D., Ed.; UNDP: Belgrade, Serbia, 2022; pp. 98–116.
3. Todorović, M.; Javor, V.; Radić, N. Emigration Potential of Youth in Serbia. *Migr. Ethn. Themes* **2021**, *36*, 155–171. [CrossRef]
4. Poleti, D. Contemporary Labour Migration in European Context–Economic and Political Aspects. *Sociologija* **2013**, *55*, 333–348. [CrossRef]
5. Stanković, V. *Srbija u Procesu Spoljnih Migracija*; Republički Zavod za Statistiku RZS: Belgrade, Serbia, 2014.
6. Despić, J. Migracije Visokoobrazovanih Lica iz Srbije od 1991. Godine u Kanadu i Sjedinjene Američke Države. Ph.D. Thesis, Faculty of Economics, University of Belgrade, Belgrade, Serbia, 2011.
7. Ravenstein, E.G. The Laws on Migration. *J. Stat. Soc. Lond.* **1885**, *48*, 167–235. [CrossRef]
8. Cassarino, J.-P. Bridging the policy gap between reintegration and development. In *Reintegration and Development*; Cassarino, J.P., Ed.; CRIS Analytical Study, Florence, European University Institute: Fiesole, Italy, 2014; pp. 1–18.
9. Thieme, S. Coming Home? Patterns and Characteristics of Return Migration in Kyrgyzstan. *Int. Migr.* **2012**, *52*, 127–143. [CrossRef]
10. United Nations. *Recommendations on Statistics of International Migration, Revision 1*; United Nations: New York, NY, USA, 1998.
11. OECD. *Return Migration: A New Perspective*; Part 3; OECD Publishing: Paris, France, 2008.
12. Ndreka, A. Return migration and Re-integration of Returnees challenges in the origin country. *RSC* **2019**, *11*, 4–24. [CrossRef]
13. Rees, P.H.; Lomax, N. Ravenstein Revisited: The Analysis of Migration, Then and Now. *Comp. Popul. Stud.* **2020**, *44*, 351–412. [CrossRef]
14. Corbett, J. *Ernest George Ravenstein: The Laws of Migration, 1885*; Center for Spatially Integrated Social Science: Santa Barbara, CA, USA, 2003; pp. 1–4.
15. Simpson, N.B. Demographic and economic determinants of migration: Push and pull factors drive the decision to stay or move. *IZA World Labor* **2022**, *373*, 1–11. [CrossRef]
16. Lee, E.S. A Theory of Migration. *Demography* **1966**, *1*, 47–57. [CrossRef]
17. Cerase, F.P. Expectations and Reality: A Case Study of Return Migration from the United States to Southern Italy. *Int. Migr. Rev.* **1974**, *8*, 245–262. [CrossRef]
18. King, R.; Kuschminder, K. Introduction: Definitions, typologies and theories of return migration. In *Handbook of Return Migration*; King, R., Kuschminder, K., Eds.; EE Edward Elgar Publishing: Cheltenham, UK, 2022; pp. 1–22.
19. Kunuroglu, F.; van de Vijver, F.; Yagmur, K. Return Migration. *Online Read. Psychol. Cult.* **2016**, *8*, 1–28. [CrossRef]
20. Cassarino, J.P. Theorising Return Migration: The Conceptual Approach to Return Migrants Revisited. *Int. J. Multicult. Soc.* **2004**, *6*, 253–279.
21. de Haas, H.; Fokkema, T.; Fihri, M.F. Return Migration as Failure or Success?: The Determinants of Return Migration Intentions Among Moroccan Migrants in Europe. *J. Int. Migr. Integr.* **2015**, *16*, 415–429. [CrossRef] [PubMed]
22. Massey, D.S.; Arango, J.; Hugo, G.; Kouaouci, A.; Pellegrino, A.J. Theories of International Migration: A Review and Appraisal. *Popul. Dev. Rev.* **1993**, *19*, 431–466. [CrossRef]
23. Gheasi, M.; Nijkamp, P. A Brief Overview of International Migration Motives and Impacts, with Specific Reference to FDI. *Economies* **2017**, *5*, 31. [CrossRef]
24. Stark, O. *The Migration of Labor*; Basil Blackwell Ltd.: Cambridge, UK, 1991.
25. Makina, D. Determinants of return migration intentions: Evidence from Zimbabwean migrants living in South Africa. *Dev. South. Afr.* **2012**, *29*, 365–378. [CrossRef]
26. Farrell, M.; Mahon, M.; McDonagh, J. The Rural as a Return Migration Destination. *Eur. Countrys.* **2012**, *4*, 31–44. [CrossRef]
27. ISN. *Social Network Analysis and Social Capital*; ISN Special Issue: Zurich, Switzerland, 2006.
28. Vanthomme, K.; Vandenheede, H. Factors Associated with Return Migration of First-Generation Immigrants in Belgium (2001–2011). *Eur. J. Popul.* **2021**, *37*, 603–624. [CrossRef]
29. Saar, M.; Saar, E. Can the Concept of Lifestyle Migration be applied to Return Migration? The Case of Estonians in the UK. *Int. Migr.* **2020**, *58*, 52–66. [CrossRef]
30. Jacobo Suárez, M.; Cárdenas Alaminos, N. Back on your Own: Return Migration and the Federal Government Response in Mexico. *Migr. Int.* **2020**, *11*, 1–22. [CrossRef]
31. Almonacid, F. Migration and Return to Mapuche Lands in Southern Chile, 1970–2022. *Sustainability* **2023**, *15*, 4457. [CrossRef]
32. Simões, F.; Rocca, A.; Rocha, R.; Mateus, C.; Marta, E.; Tosun, J. Time to Get Emotional: Determinants of University Students' Intention to Return to Rural Areas. *Sustainability* **2021**, *13*, 5135. [CrossRef]
33. Duda-Mikulin, E. Should I stay or should I go now? Exploring Polish women's returns "home". *Int. Migr.* **2018**, *56*, 140–153. [CrossRef]
34. Kunuroglu, F.; Yagmur, K.; Van De Vijver, F.; Kroon, S. Motives for Turkish return migration from Western Europe: Home, sense of belonging, discrimination and transnationalism. *Turk. Stud.* **2018**, *19*, 422–450. [CrossRef]
35. Hirvonen, K.; Bie Lilleør, H. Going Back Home: Internal Return Migration in Rural Tanzania. *World Dev.* **2015**, *70*, 186–202. [CrossRef]

36. Wong, M. Navigating return: The gendered geographies of skilled return migration to Ghana. *Glob. Netw.* **2014**, *14*, 438–457. [CrossRef]
37. Yahirun, J. Take Me "Home": Return Migration among Germany's Older Immigrants. *Int. Migr.* **2012**, *52*, 231–254. [CrossRef]
38. Czeranowska, O.; Parutis, V.; Trąbka, A. Between settlement, double return and re-emigration: Motivations for future mobility of Polish and Lithuanian return migrants. *Comp. Migr. Stud. CMS* **2023**, *11*, 28. [CrossRef]
39. Niedomysl, T.; Amcoff, J. Why return migrants return: Survey evidence on motives for internal return migration in Sweden. *Popul. Space Place* **2010**, *17*, 656–673. [CrossRef]
40. Matloob, P. Occupational choice of return migrants. *IZA World Labor* **2015**, *197*, 1–10. [CrossRef]
41. Grosa, D.; King, R. The Challenges of Educational Reintegration and the Psychosocial Wellbeing of Returnee Children: Evidence from Latvia. *Int. Migr. Integr.* **2023**, *24*, 407–426. [CrossRef] [PubMed]
42. Donato, S. Women Migrant Returnees as Intermediaries: Exploring Empowerment and Agency of Migrant Women Returnees in the EU-MENA Region. *Int. Migr. Integr.* **2023**, 1–17. [CrossRef]
43. Rajan, S.I.; Amuthan, S. Labour Force, Occupational Changes and Socioeconomic Level of Return Emigrants in India. *Int. Migr. Integr.* **2022**, *23*, 865–887. [CrossRef]
44. Kuschminder, K. *Reintegration Strategies Conceptualizing How Return Migrants Reintegrate*; Palgrave MacMillan: London, UK, 2017; Available online: https://hdl.handle.net/1814/47704 (accessed on 10 June 2024).
45. Black, R.; Gent, S. *Defining, Measuring and Influencing Sustainable Return: The Case of the Balkans*; Development Research Centre on Migration, Globalisation and Poverty: Brighton, UK, 2004.
46. Knoll, A.; Veron, P.; Mayer, N. *A Sustainable Development Approach to Return and Reintegration: Dilemmas, Choices and Possibilities*; The European Centre for Development Policy Management (ECDPM): Maastricht, The Netherlands, 2021.
47. Strachan, A.L. Reintegration of returnees. In *K4D Helpdesk Report 572*; Institute of Development Studies: Brighton, UK, 2019.
48. Whyte, Z.; Hirslund, D. *International Experiences with the Sustainable Assisted Return of Rejected Asylum Seekers*; Danish Institute for International Studies (DIIS): Copenhagen, Denmark, 2013.
49. Black, R.; Gent, S. Sustainable return in post-conflict contexts. *Int. Migr.* **2006**, *44*, 15–38. [CrossRef]
50. OECD. *Sustainable Reintegration of Returning Migrants: A Better Homecoming*; OECD Publishing: Paris, France, 2020.
51. Hausmann, R.; Nedelkoska, L. *Effects of Return Migration on the Non-Migrants' Wages and Employment*; CID Faculty WP 330: Cambridge, MA, USA, 2017.
52. Martin, R.; Radu, D. Return Migration: The Experience of Eastern Europe. *Int. Migr.* **2012**, *50*, 109–128. [CrossRef]
53. Wiesbrock, A. Return Migration as a Tool for Economic Development in China and India. IMDS WP Series. 2008. Available online: https://www.researchgate.net/publication/267978454_Return_Migration_as_a_Tool_for_Economic_Development_in_China_and_India (accessed on 17 January 2024).
54. Chobanyan, H. *Return Migration and Reintegration Issues: Armenia*; European University Institute Robert Schuman Centre for Advanced Studies: Florence, Italy, 2013.
55. Tačka Povratka. Available online: https://tackapovratka.rs/vodiczapovratnike/ (accessed on 16 January 2024).
56. *Economic Migration Strategy of the Republic of Serbia 2021–2027*; No. 21/2020-45; Official Gazette of the Republic of Serbia: Belgrade, Serbia, 2020.
57. Vesković Anđelković, M. Potential Role of Returnees as Intermediaries in the Partnership between the State and Higly Educated Diaspora in Serbia. Ph.D. Thesis, University of Belgrade Faculty of Philosophy, Belgrade, Serbia, 2019.
58. Vasojević, N.; Krnjaić, Z.; Kirin, S. Scholarship holders abroad: Returnees in the academic community in Serbia. *Sociološki Pregl.* **2018**, *52*, 938–959. [CrossRef]
59. Vasojević, N.; Kirin, S. Life satisfaction of returnee scholarship holders in Serbia. *Stanovništvo* **2019**, *57*, 71–86. [CrossRef]
60. Bodrožić, Z. The return of highlyskilled migrants to Serbia. *Psihol. Istraživanja* **2014**, *17*, 55–75. [CrossRef]
61. Pavlov, T. Return of Higly Qualified Migrants to Serbia: 'Brain Gain' Instead of Facing 'Brain Re-Drain'. In *Return of Highly Qualified Migrants to the Western Balkan*; Petronijević, V., Ed.; Group 484, The Balkan Trust for Democracy: Beograd, Serbia, 2011; pp. 7–28.
62. Pavlov, T.; Predojević-Despić, J.; Milutinović, S. Transnational Entrepreneurship: Experiences of Migrant-Returnees to Serbia. *Sociologija* **2013**, *55*, 261–282. [CrossRef]
63. Šantić, D.; Todorović, M. Between desires and reality: Investigating the return intentions among the second generation members of migrants from Serbia in Switzerland. *Matica Srp. Soc. Sci.* **2021**, *77*, 91–108. [CrossRef]
64. Todorović, M. Challenges of transnationalism among the second generation of Serbian migrants in Switzerland. *Bull. Serbian Geogr. Soc.* **2019**, *1*, 69–90. [CrossRef]
65. Predojević Despić, J.; Lukić, V. Challenges faced by Serbian migrants caused by the COVID-19 pandemic. *TEME* **2021**, *45*, 1245–1260. [CrossRef]
66. Vesković Anđelković, M. The experiences and expectations of returnees to Serbia during the COVID-19 pandemic. *Stanovništvo* **2021**, *59*, 47–60. [CrossRef]
67. Šantić, D.; Todorović, M.; Perišić, N. The 'New Normal' in Migration Management in Serbia in Times of the COVID-19 Crisis. *J. Balk. Near East. Stud.* **2021**, *24*, 557–575. [CrossRef]
68. Pešić, J. COVID-19, mobility and self-isolation. Experiences of the Serbia's citizens in the times of global pandemic. *Sociologija* **2020**, *62*, 467–485. [CrossRef]

69. Šantić, D.; Antić, M. Serbia in the time of COVID-19: Between "corona diplomacy", tough measures and migration management. *Eurasian Geogr. Econ.* **2020**, *61*, 546–558. [CrossRef]
70. Schmitz-Pranghe, C. The role of mobility, networks and reintegration assistance after return: Insights from Bosnia and Herzegovina and Serbia. In *BICC Working Paper, 1/2023*; Bonn International Centre for Conflict Studies (BICC): Bonn, Germany, 2023.
71. Nikitović, V. Višeslojna priroda depopulacije u Srbiji–noviji trendovi i izgledi. In *Ljudski Razvoj kao Odgovor na Demografske Promene*; Vuković, D., Ed.; UNDP Serbia: Belgrade, Serbia, 2022; pp. 53–72.
72. Statistical Office of the Republic of Serbia. *Migrations Data by Municipalities and Cities 2022*; SORS: Belgrade, Serbia, 2023.
73. Predojević-Despić, J. Prostorne karakteristike emigracije iz Srbije: Od gastarbajtera do migrantskih mreža. *Demogr. Pregl.* **2011**, *11*, 1–4.
74. Statistical Office of the Republic of Serbia. *Economic Activity Data by Municipalities and Cities 2011*; SORS: Belgrade, Serbia, 2013.
75. Statistical Office of the Republic of Serbia. *Educational Attainment, Literacy and Computer Literacy 2011*; SORS: Belgrade, Serbia, 2013.
76. Statistical Office of the Republic of Serbia. *Return Migrants in Serbia by Municipalities 2011*; Unpublished Data; SORS: Belgrade, Serbia, 2023.
77. Pallant, J. *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows*, 3rd ed.; Open University Press: Berkshire, UK, 2007.
78. IOM; UN Women. *Manual for Inclusive and Sustainable Reintegration of Returning Migrant Workers in South Asia*; IOM and UN Women Regional Office for Asia and the Pacific: Colombo, Sri Lanka; Bangkok, Thailand, 2023.
79. Šantić, D.; Konjević, J.; Langović, M. The importance of creating migration profiles in local self-government units for the optimal management of migration and their integration into development documents. In Proceedings of the IX Scientific-Professional Conference with International Participation "Local Self-Government in Planning and Arrangement of Space and Settlements", Srebrno Jezero, Serbia, 16–18 June 2022.
80. Segeš Frelak, J.; Hahn-Schaur, K. *Attract, Facilitate and Retain–Return Migration Policies in the Context of Intra-EU Mobility*; ICMPD International Centre for Migration Policy Development: Vienna, Austria, 2019.
81. Segal, U. Opportunities and challenges of return migration. In *Migrant Workers: Social Identity, Occupational Challenges and Health Practice*; Xu, Q., Jordan, L., Eds.; Nova Science Publishers: Hauppauge, NY, USA, 2016; pp. 171–190.
82. Global Forum on Migration & Development. Available online: https://www.gfmd.org/roundtable-2-background-papers-0 (accessed on 11 January 2024).

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Crosswalking the EU Nature Restoration Regulation and the Kunming-Montreal Global Biodiversity Framework: A Forest-Centred Outlook

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Abstract: Following the adoption of the Kunming-Montreal Global Biodiversity Framework (KM-GBF) under the Convention on Biological Diversity, the European Union (EU) introduced an EU Nature Restoration Regulation. This study systematically compares the restoration regulation with the KM-GBF, focusing on their implications for forest ecosystems. The paper identifies areas of alignment, divergence, and potential gaps concerning habitat restoration, species protection, climate resilience, and sustainable natural resource use. Employing a grounded methodology, the analysis begins with the 23 KM-GBF targets and proceeds to the 28 articles of the restoration regulation. The findings underscore the need for better alignment between the KM-GBF, the restoration regulation, and other forest-related EU policies. The study emphasises the importance of a coherent and integrated EU policy approach to address the complex challenges and varied policy objectives facing forests. It concludes that amendments to the restoration regulation have significantly diluted its potential impact, limiting the EU Member States' accountability and ability to meet KM-GBF goals and targets. It further stresses the need for strategies to reconcile divergent EU policy pathways, support forest management and restoration efforts, and align with global biodiversity objectives.

Keywords: EU nature restoration regulation; Kunming-Montreal Global Biodiversity Framework; policy implementation; forest restoration; EU forest policy

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1. Introduction

In the wake of the largely unsuccessful global effort to meet the Aichi targets [1,2] set by the Convention on Biological Diversity (CBD), the international community has shifted its focus to the Kunming-Montreal Global Biodiversity Framework (KM-GBF). Ratified by 195 countries during the 15th Conference of the Parties (COP15) to the CBD in 2022, this new framework establishes a revised agenda to halt and reverse biodiversity loss. It covers 23 action-oriented global targets to be met by 2030 and four goals for 2050 [3]. The overarching goals (Appendix A) are linked to "*the shared vision of living in harmony with nature*" (annex, para. 3) by 2050. The increased ambition of the KM-GBF targets, as compared to the Aichi targets, combined with an accelerating biodiversity and climate crisis [4,5], suggest the need for urgent research and policy action to help guide and improve international and national efforts in stemming and reversing global biodiversity loss [6,7].

Following the adoption of the KM-GBF, the European Union (EU) recently reached an agreement on a nature restoration regulation. The initial proposal for a restoration regulation was published in 2022 [8] as an integral part of the Biodiversity Strategy for 2030 [9]. It is considered a key instrument to "*help the EU reach its international commitments, in particular the UN Kunming-Montreal global biodiversity framework*" [10]. The regulation is an integral component of the European Green Deal, aimed at combating environmental degradation [11], seeking to establish binding restoration targets for specific ecosystems and species, thereby ensuring recovery and long-term resilience. The regulation's objectives are, as such, intrinsically connected with the goals and targets set out in the KM-GBF,

representing an EU-wide effort to halt and reverse biodiversity loss and a regional response to the global call for action communicated within the KM-GBF.

Considering the EU's efforts to address global biodiversity loss, the interplay between the restoration regulation and the KM-GBF, particularly in the context of forest ecosystems and the forest-based sector, emerges as a relevant area for analysis. As an important reservoir of biodiversity, forests occupy a central role in the restoration regulation and the KM-GBF. Moreover, the focus on forests within the EU's legislative framework on restoration is representative of the global recognition of the need to prioritise forest ecosystems. Zooming in on forests, this paper will consider how the restoration regulation aligns with and supports the global biodiversity goals and targets, specifically those related to forest ecosystems. Focusing on forests will allow for a detailed review of the regulation's potential to drive meaningful change in forest conservation and restoration.

The objective of this paper is twofold. First, it will set out to identify and crosswalk relevant provisions within the EU Nature Restoration Regulation alongside the goals and targets of the KM-GBF. As noted above, to delimit the analysis, the focus will be on articles, goals, and targets that can be considered relevant to forest ecosystems and the forest-based sector. Second, the paper will evaluate the potential efficacy of the EU Nature Restoration Regulation in fulfilling forest-relevant goals and targets established under the KM-GBF. The paper will also assess potential gaps in the EU Nature Restoration Regulation that might be addressed through other EU forest-relevant policy instruments. The review will not address the KM-GBF monitoring framework (e.g., headline, component and complementary indicators) being considered by the Ad Hoc Technical Expert Group on Indicators (AHTEG), as set out in CBD decision 15/5 [12].

2. Background

2.1. Kunming-Montreal Global Biodiversity Framework

The KM-GBF is a multilateral treaty that addresses the three objectives of the CBD in an integrative manner: (1) the conservation of biological diversity, (2) the sustainable use of its components, and (3) the fair and equitable sharing of benefits arising from genetic resources [3]. The KM-GBF's development, its relationship with the Aichi targets, its own goals and targets, and the role of the AHTEG are key to understanding its implementation strategy:

- The KM-GBF was developed in response to the mixed success of the Aichi targets [2,4,13], which were part of the Strategic Plan for Biodiversity 2011–2020 [1]. The KM-GBF can be conceptualised as an evolution of the Aichi targets to address the gaps and challenges faced during its implementation. The KM-GBF has tried to fix these failings by establishing more ambitious targets, emphasising that biodiversity considerations should be integrated into all economic sectors while emphasising the accountability of state and non-state actors. This shift towards more actionable, quantifiable, and inclusive conservation reflects a more adaptive governance paradigm.
- The KM-GBF is to be implemented based on the ecosystem approach of the CBD (Decision V/6), based on scientific evidence and traditional knowledge and practices (annex, para. 19), guided by the principle of intergenerational equity (annex, para. 21), with consideration of the One Health Approach (annex, para. 25). It further stresses the need for transformative actions (annex, para. 4) that can address biodiversity loss, including changes in consumption patterns, land-use practices, and economic systems that undervalue natural capital.
- While acknowledging different value systems associated with biodiversity (e.g., par. 7(b)), the KM-GBF predominantly aligns with anthropocentric perspectives, such as in targets 9 and 11. It focuses on nature restoration to "*maintain and enhance nature's contributions to people*" (target 11) while being "*guided by the principle of intergenerational equity*" (par. 7(n)). This deviates from ecocentric or biocentric viewpoints, suggesting it is geared towards human-centric (or anthropocentric) outcomes.

- The framework sets specific targets (Table 1), for example, to conserve at least 30 per cent of the global land and sea areas by 2030 (targets 2 and 3), reduce pollution (target 7), and address the impacts of climate change on biodiversity (target 8). Key to its implementation strategy is mainstreaming biodiversity across government policies, the private sector, and societal actions.

Table 1. Crosswalking KM-GBF targets with articles in the restoration regulation.

KM-GBF Targets *	Articles in the Regulation on Nature Restoration	Notes
Target 1: Reducing biodiversity loss. Target 2: Restoring degraded ecosystems. Target 3: Conserving biodiversity. Target 4: Halt and reverse extinction. Target 5: Sustainable use, harvesting and trade of wild species.	Article 1. Subject matter. Article 4: Restoration of terrestrial, coastal and freshwater ecosystems. Article 10: Restoration of forest ecosystems. Article 10a: Planting of three billion additional trees. ** Article 11: Preparation of the national restoration plans.	• Aim to restore at least 20% of land by 2030 (art. 1, para. 2). • Contribute to the EU's overarching objective for land degradation neutrality (art. 1, par. 1 (b)). • Restoration measures must be taken for at least 30% of habitat types (listed in Annex I) that are not in good condition by 2030, 60% by 2040, and 90% by 2050 (art. 4, par. 1). • The target may be lowered if 3% of the national territory contains the habitat type listed in Annex I (derogation), lowering the overall target to "one-third of that percentage by 2030" (art. 4, par. 1a and 2b). • Restoration measures in Natura 2000 sites will be given priority until 2030 (art. 4, par. 1). • Show a continuous improvement in the condition of the habitat types (art. 4, par. 6 and 10) and prevent significant deterioration (art. 4, par. 7). • Restoration measures to enhance the biodiversity of forest ecosystems are in addition to other measures (art. 10, par. 1), including the commitment to planting three billion trees by 2030 (art. 10a, par. 1). • Restoration measures for species listed in the Habitats and Birds Directives (92/43/EEC and Directive 2009/147/EC) (art. 4, par. 3). • Sustainable afforestation, reforestation and tree planting and the greening of urban areas (art. 10a, par. 2). • Trade of wild species is not addressed.
Target 6: Invasive alien species.	Articles 11 and 12: National restoration plans. Annex VII: Restoration measures.	• Removal and control of invasive alien species are only noted as possible restoration measures (annex VII, par. 22).
Target 7: Reduce pollution risks and impacts.		• Pollution is noted in preparing national restoration plans and associated EU regulations, such as Directive 2016/2284 (art. 11, par. 7(e), annex VII, par. 28 and 30).
Target 8: Minimise the impact of climate change.	Article 4: Restoration of terrestrial, coastal and freshwater ecosystems. Article 5a: Energy from renewable sources.** Article 10: Restoration of forest ecosystems. Article 10a: Planting of three billion additional trees. ** Articles 11 and 12: National restoration plans.	• Mainly relevant for Natura 2000 sites in cases where habitat transformations are directly caused by climate change (art. 4, par. 9). • Exceptions included for energy production from renewable sources (art. 5a). • Obligations are non-binding for the restoration of forest ecosystems if habitat transformations are directly caused by climate change (art. 10, par. 2b).

Table 1. *Cont.*

KM-GBF Targets *	Articles in the Regulation on Nature Restoration	Notes
Target 9: Sustainable management and use of wild species.	Article 4: Restoration of terrestrial, coastal and freshwater ecosystems.	• Restoration measures for species listed in the Habitats and Birds Directives (92/43/EEC and Directive 2009/147/EC) (art. 4, par. 3).
Target 10: Sustainable land-use.	Article 8: Restoration of pollinator populations. Article 9. Restoration of agricultural ecosystems. Annex IV: Biodiversity indicators. Annex VII: Restoration measures.	• Ensure sustainable agricultural production (art. 9, par. 1). • Sustainable agroforestry systems are part of the biodiversity indicators for agricultural ecosystems (annex IV). • Increase the agricultural area subject to agro-ecological management approaches (annex VII, par. 16).
Target 11: Restore/enhance ecosystem functions and services.	Article 1. Subject matter. Article 4: Restoration of terrestrial, coastal and freshwater ecosystems. Articles 11 and 12: National restoration plans. Annex VII: Restoration measures.	• Aim to restore at least 20% of land by 2030 (art. 1, para. 2). • Aim at optimising ecosystems' ecological, economic, and social functions (art. 11, par. 9). • Ecosystem function is a factor in selecting a restoration area (art. 4, para. 4). • Enhance the development of old-growth native forests and mature stands favouring autoregulatory functions (annex VII, par. 14).
Target 12: Connectivity and access to urban green and blue spaces.	Article 4: Restoration of terrestrial, coastal and freshwater ecosystems. Article 6: Restoration of urban ecosystems. Article 10: Restoration of forest ecosystems. Article 10a: Planting of three billion additional trees.** Articles 11 and 12: National restoration plans. Annex VII: Restoration measures.	• Increased urban green space (e.g., urban tree canopy cover), including buildings and infrastructure (art. 6, par. 1–2), and including restoration measures (annex VII, par. 29). • Greening of urban areas (art. 10a, par. 2). • Connectivity mainly in terms of improved ecological coherence and connectivity of habitats (art. 4, par. 3 and 5, art. 10a, par. 2, art. 11, par. 2 (b)). • Forest connectivity is a target indicator (art. 10, par. 2a (d)). • Identify/map urban ecosystems and forest areas for restoration, particularly areas that need enhanced connectivity and landscape diversity (art. 11, par. 2b-4).
Target 13: Use of genetic resources.	Annex VII: Restoration measures.	• Only noted in improving connectivity and genetic exchange (annex VII, par. 21).
Target 14: Integration of biodiversity into policies, regulations, planning and development processes.	Articles 11 and 12: National restoration plans.	• Restoration measures are prioritised based on synergies with CC mitigation and adaptation, land degradation neutrality, and disaster prevention (art. 11, par. 5). • Identify synergies with agriculture and forestry (art. 11, par. 5a). • Co-benefits for CC mitigation and land degradation neutrality associated with restoration (art. 12, par. 2 (j)).
Target 15: Enable business.		• Not applicable: see Appendix C.
Target 16: Sustainable consumption choices.		• Not applicable: see Appendix C.
Target 17: Strengthen capacity for biosafety measures.		• Not applicable: see Appendix C.
Target 18: Phase out or reform incentives harmful to biodiversity.		• Not applicable: see Appendix C.

Table 1. *Cont.*

KM-GBF Targets *	Articles in the Regulation on Nature Restoration	Notes
Target 19: Increase the level of financial resources for biodiversity.	Article 8: Restoration of pollinator populations. Article 11: National restoration plans. Article 18: Reporting.	• Promotes financing of citizen science (art. 8, par. 3a). • Promotes the use of private or public support schemes for implementing restoration measures (art. 11, 5c). • Under the CAP, CFP, or other funding programs, no reprogramming of funding is required (art. 11, par. 5b). • Funding gaps will only be addressed in the multiannual financial framework post-2027 (art. 18, par. 6a (d)). • Countries must report whether they have met financing needs (art. 18, par. 2 (e)).
Target 20: Strengthening scientific research, cooperation, and monitoring capacities.	Article 4: Restoration of terrestrial, coastal and freshwater ecosystems. Article 17: Monitoring.	• Does not address cooperation on forests (only for marine ecosystems), and research only covers site selection and monitoring. • Research/scientific evidence for selecting restoration sites (art. 4, par. 4). • Research/scientific evidence to identify restoration measures (art. 11, par. 1). • Promoting citizen science (art. 8, par. 3a, art. 17, par. 8).
Target 21: Access to data and knowledge.	Article 8: Restoration of pollinator populations. Articles 11 and 12: National restoration plans. Article 17: Monitoring. Article 18: Reporting.	• Monitor high-diversity landscape features (art. 11, par. 4a) and forests (art. 17, par. 5). • Monitoring of pollinator diversity and populations (art. 8, par. 2, 3(a). • Identification and monitoring of restoration measures/sites (art. 11, par. 1, art. 12, par. 2(ca) and (h), art. 17, par. 1–8, art. 18, par. 2 (b)). • Access and use of data (art. 17, par. 7–8, art. 18, par. 7).
Targets 22 and 23: Gender equality and representation.		• Not applicable.

* Complete targets can be found in the KM-GBF [3]. ** Numbering of articles likely to change in the published version.

2.2. The EU Regulation on Nature Restoration

The EU Nature Restoration Regulation proposal in 2022 was a policy effort by the European Commission (EC) for legally binding EU targets to restore nature and repair damaged ecosystems, aiming to cover 30 per cent of the EU's land and sea areas by 2030 [8]. In a nutshell, the restoration regulation set out to achieve long-term and sustained recovery of biodiverse land and sea areas, contributing to relevant biodiversity and climate objectives as well as supporting economic recovery and resilience.

- Work on the restoration regulation started as part of the EU Biodiversity Strategy for 2030 [9], a core component of the European Green Deal [11]. The EC proposed this regulation to set binding restoration targets for specific habitats and species, such as binding targets on pollinators, wetlands, rivers, forests, marine ecosystems, urban areas, and peatlands. The aim was to cover most of the EU's land areas and water bodies (freshwater and marine environments). The development process involved scientific research, stakeholder consultations, and impact assessments to ensure an achievable regulation.
- By trying to set legally binding restoration targets, the EU aimed to contribute to the global goal of restoring 30 per cent of degraded ecosystems by 2030. This was later reduced to 20 per cent by the European Parliament in 2023 [14]. The regulation establishes specific targets for various ecosystems, including forests. It emphasises the restoration of biodiversity-rich habitats, the re-establishment of natural processes, and the recovery of species populations. The regulation sets out a mix of mandatory and voluntary measures to achieve these objectives, supported by financial mechanisms

and technical assistance to EU Member States (EU MSs). It also includes mechanisms for monitoring, reporting, and evaluating progress towards the targets.

It should be noted that the text of the provisional agreement on the nature restoration regulation [14], which was revised by the European Parliament (June 2023) and by the Council of Europe (November 2023), is going through the final stages of the ordinary legislative procedure. The regulation has been formally adopted by Parliament (February 2024) and will enter into force in 2024 (or 20 days after adoption by the Council).

3. Materials and Methods

This study employed text-based content analysis to crosswalk two policy documents that mark recent international and regional commitments on biodiversity: the EU Nature Restoration Regulation [14] and the Kunming-Montreal Global Biodiversity Framework [3]. The analysis involved a systematic review and comparison of these policy documents to understand their implications for forest and biodiversity restoration [15,16]. Specifically, the analysis aimed to identify areas of alignment, divergence, and potential gaps, covering key themes such as habitat restoration, species protection, climate resilience, and the sustainable use of natural resources. The comparative analysis took a grounded approach. It started by focusing on the targets in the KM-GBF. Then, it moved on to the articles in the EU Nature Restoration Regulation, which allowed for the emergence of similarities and differences between the documents [17,18].

The analysis began by marking, annotating, and summarising sections relevant to forests in both documents. This process involved noting instances where forest-relevant topics were addressed, directly or indirectly, comparing the language, commitments, and strategies proposed within the respective policy documents. Forest-relevant refers to any information in the documents that may have implications for forests, from direct (e.g., specific references to forestry practices) to indirect (e.g., climate policies and land use strategies) implications.

Given that the analysis principally focused on two policy documents, it was decided to apply a manual approach, marking relevant text in the PDFs and transferring it to an Excel file for further analysis.

The comparative analysis focused on identifying similarities and differences in how each document addresses forest-relevant topics. This process started by listing the targets in the KM-GBF against relevant articles in the restoration regulation to reveal areas of convergence, such as shared goals for habitat restoration and species protection, as well as divergence, particularly in the specificity of targets and mechanisms for implementation and monitoring. Comparing the policy documents side by side made it possible to determine how much they align.

Once it became apparent that the restoration regulation did not address several targets in the KM-GBF, a crosswalk was carried out between the KM-GBF and other EU policy instruments. This was not an in-depth comparison and analysis but simply an additional step to identify what EU policy domains and instruments may be relevant in terms of coverage (Appendix C). It was essentially a topical review whereby policy instruments were identified using the EUR-Lex (see https://eur-lex.europa.eu/homepage.html, accessed on 5 June 2024) and relevant EC websites (e.g., DG Env and DG Clima) using keywords from each KM-GBF target (e.g., target 5: trade of wild species).

4. Analysis and Results

4.1. General Comparison

There is a significant legal difference between the restoration regulation and the KM-GBF. Once in force, the restoration regulation will be legally binding for EU MS, whereas the KM-GBF is a non-binding framework. The EU regulation is also region-specific, whereas the KM-GBF has a global focus. More importantly, however, compliance with the restoration regulation can be enforced through relevant EU mechanisms. In contrast, compliance with

the KM-GBF relies on the Contracting Party's commitment to integrate its goals and targets into national policies and actions [6].

The KM-GBF and the restoration regulation offer complementary yet distinct approaches to biodiversity and ecosystem conservation and restoration. The KM-GBF sets out 23 global targets (Table 1) aimed at reducing threats to biodiversity, promoting sustainable use, and facilitating benefit-sharing. It focuses on broad, actionable goals to protect and restore biodiversity on a global scale, including specific targets to prevent species extinction and reduce pollution impacts directly. In contrast, the restoration regulation adopts a more focused strategy, detailing 28 articles (Appendix B) that outline measures for restoring specific ecosystems, which indirectly contribute to broader biodiversity objectives, such as species conservation through habitat restoration and sustainable use via agricultural ecosystem restoration. Nine of these targets concern the delegation of powers, and committee procedures (Chapter V) and final provisions (Chapter VI) and are seen as less relevant [14]. While the KM-GBF explicitly addresses climate change impacts and advocates for sustainable consumption patterns, the restoration regulation emphasises restoration actions that have indirect benefits, like improving ecosystem health, which may, in turn, influence consumption patterns.

The restoration regulation includes detailed monitoring and reporting requirements to support restoration efforts (Chapter IV). In contrast, the KM-GBF emphasises broader monitoring and accessibility of data and knowledge for biodiversity governance [12]. Both frameworks underscore the importance of nature-based solutions—approaches that use natural processes and ecosystems to tackle societal challenges, enhance biodiversity, and improve human well-being—and financial shifts towards sustainability; however, they differ in their directness and specificity of targets. For example, the restoration regulation's focus on specific restoration actions exemplifies nature-based solutions through targeted ecosystem restoration projects. At the same time, the KM-GBF's broader approach includes sustainable resource management and consumption patterns that incorporate nature-based solutions on a larger scale. Additionally, the KM-GBF's explicit targets on genetic resources and harmful subsidies highlight its wider governance perspective compared to the restoration regulation's detailed restoration strategies and monitoring requirements.

4.2. Forests, the KM-GBF, and the Restoration Regulation

4.2.1. Kunming-Montreal Global Biodiversity Framework

- Only one KM-GBF target refers directly to forests. Target 10 sets out a requirement to ensure that areas under "*forestry are managed sustainably, in particular through the sustainable use of biodiversity*" (p. 10). However, forestry represents a broad range of activities that covers a wide spectrum of sectors, from timber production to non-wood forest products.
- All 23 KM-GBF targets can be considered as having direct and indirect implications for forests and the European forest-based sector (Table 1). For instance, "*reducing biodiversity loss*" (target 1) is relevant as forests harbour a significant portion of the world's terrestrial species, and "*encouraging sustainable consumption choices*" (target 16) may affect the demand for forest-based products.
- Based on the crosswalk between the articles of the restoration regulation and the KM-GB, 17 targets (74%) can be considered as having some degree of importance (Table 1). The remaining six targets (26%) were not included. For instance, the targets on gender (targets 22–23) are not relevant, as the restoration regulation does not address any gender issues, which means these targets were excluded from the crosswalk.
- For the crosswalk between the KM-GBF targets and other EU policy instruments, targets 17, 19, 20, and 22–23 were excluded as they were considered only indirectly important in terms of EU forest-relevant policy, such as addressing technology transfer, biosafety measures, resource mobilisation, and gender equity (Appendix C).

4.2.2. EU Regulation on Nature Restoration

- The restoration regulation emphasises restoration measures to enhance forest biodiversity, considering risks such as forest fires, while aiming for an "*increasing trend at national level of the common forest bird index*" (article 10). It further sets out measures (annex VII) and indicators related to deadwood, forest structure, connectivity, carbon stock, and species diversity (article 17, annexes IV and VI).
- Seven articles (1, 4, 5a, 6, 10, 10a, and 17) can be considered directly relevant for forests and the forest-based sector, particularly article 5a on energy from renewable resources, article 10 on the restoration of forest ecosystems, and article 10a on the planting of three billion additional trees [14].
- Six articles can be considered indirectly relevant, covering the restoration of rivers' natural connectivity and the natural functions of the related floodplains (article 7); restoration in agricultural contexts, which also indirectly affects forest ecosystems, emphasising biodiversity and organic soil restoration (article 9); and articles associated with the development and adoption of restoration plans (articles 11 to 14).

4.3. Crosswalking the Targets and Articles in the KM-GBF and EU Regulation on Nature Restoration

The analysis of the KM-GBF and the restoration regulation reveals some complementary approaches in the context of forest restoration and sustainable practices (Table 1). Generally, the KM-GBF provides broad targets for biodiversity, which are not forest-specific. In contrast, the restoration regulation sets out concrete forest-relevant measures (e.g., tree planting and establishing riparian forests) that are quantifiable and attached to a detailed monitoring framework (as set out in articles 17 and 18), including forest-specific biodiversity indicators (annex VI). Furthermore, the restoration regulation's focus on enhancing ecosystem services and connectivity supports the KM-GBF's aim for improved connectivity, human well-being, and sustainable land use indirectly (e.g., goal A, targets 2–3 and 12). However, while the restoration regulation notes measures for forest ecosystems, there may be gaps in addressing targets, such as those related to invasive species and pollution reduction. This would suggest the need for enhanced alignment, particularly with other relevant EU policy instruments, to translate the global targets into specific regional actions (Appendix C).

Article 1 of the restoration regulation calls for EU MSs to have restoration measures in place by 2030 in "*at least 20% of land and 20% of the sea areas and, by 2050, all ecosystems in need of restoration*" (para. 2) is a Union target. This means it is not a commitment on the EU MS level but refers to an EU-wide average. Moreover, as part of the first reading, the negotiations in the European Parliament resulted in two significant amendments that essentially watered down the restoration regulation. First, the original restoration target was reduced from 30 to 20 per cent. This effectively means the restoration regulation does not reach the 30 per cent target set out in the KM-GBF (targets 2 and 3). Arguably, the EU Biodiversity Strategy for 2030 may help to address this concern, as it sets out to legally protect at least 30 per cent of the EU's land and sea area [9]; however, this is a soft (non-binding) policy instrument as compared to the restoration regulation. Second, several articles were changed from hard commitments to subjective aims. For example, articles (e.g., 4 to 6) were amended to note that EU MSs only need to "aim" to ensure that relevant measures are in place, which principally turn these policy objectives into non-binding targets. This implies that the restoration regulation will not ensure that EU MSs reach several KM-GBF goals and targets listed in Table 1. It also raises concerns about whether individual EU MSs, all signatories to the CBD, can reach these area-based conservation targets.

Specific to forests and the restoration regulation, Parliament also added an article relating to the production of energy from renewable sources (article 5a). From a climate perspective, there may be some grounds for this addition [19–21]; however, the article also allows for restoration and conservation targets to be overridden for energy production as it

is presumed to be an "*overriding public interest*". Moreover, increasing bioenergy sourced from forest biomass for renewable energy production conflicts with forest conservation goals [22–24]. For example, a recent study by Stubenrauch and Garske [25], which analysed the trade-offs between renewable energy targets and forest conservation in Europe, demonstrates that subsidised energy use of biomass by the renewable energy directive (RED III) endangers carbon sinks and forest biodiversity.

Another climate-related issue, recognised in the restoration regulation, concerns EU objectives regarding the accounting of emissions and removals from land use, land use change and forestry ('LULUCF'). For the LULUCF sector, "*it is important that ecosystems in all land categories, including forests, grasslands, croplands and wetlands, are in good condition in order to be able to effectively capture and store carbon*" (para. 18). While the need for restoration is highlighted, increasing carbon sequestration may not mean it is good for biodiversity [20,26–28]. Moreover, efforts to maximise carbon sequestration in forests for climate change mitigation, such as afforestation or reforestation, may conflict with other forest management objectives, such as timber production [29]. This raises concerns about whether conflicting policy objectives may allow the restoration regulation to be overridden in pursuing carbon neutrality [20,21,29].

Finally, from a forest perspective, the restoration regulation notes that some restoration measures "*may in certain cases require the removal of forest in order to reinstall conservation-driven management*" (para. 29a). Examples include restoring original habitat types, such as grasslands, heaths, or wetlands, which have been converted into forests. This highlights the complex interplay between competing conservation goals and land-use priorities. While this approach may align with the broader objectives of the KM-GBF, it also presents a dilemma for forest management, as it will require a balancing act between maintaining forest cover, which is important for carbon sequestration and climate regulation, and restoring forest ecosystems that have been identified as priorities for biodiversity conservation. This represents an important trade-off between biodiversity conservation and forest management interventions and stresses the need to consider multiple objectives [30–32]. It also emphasises the need for clear guidelines and criteria to determine whether, when, and where forest removal for restoration purposes is justified.

5. Discussion and Conclusions

The crosswalk between forest-relevant provisions in the EU Nature Restoration Regulation and the Kunming-Montreal Global Biodiversity Framework reveals different legal and operational approaches taken by the two policy instruments. The former is legally binding and region-specific, while the latter serves as a non-binding global framework. The analysis reveals the potential efficacy of the restoration regulation in addressing forest-relevant targets under the KM-GBF (Table 1), and it shows some of the potential gaps in the restoration regulation that might be addressed through other forest-relevant EU policy instruments (Appendix C). Aside from legal differences, the crosswalk further highlights that the KM-GBF represents broad and action-oriented goals and targets, focusing on reducing threats to biodiversity, sustainable use, and sharing benefits. In contrast, the restoration regulation specifies detailed measures and targets for restoring specific ecosystems, indirectly supporting the broader biodiversity goals through focused restoration actions.

The reduction of the restoration regulation's target (from 30 to 20 per cent) and the shift from binding commitments to aims suggests that EU MSs may not be willing (or able) to meet the KM-GBF targets. Amendments by the European Parliament weakened the prospective enforcement mechanisms of the regulation, undermining EU MS accountability in fulfilling biodiversity commitments. Even more, countries can now weigh economic factors in restoration planning (article 11), which may lead to uneven commitment levels across EU MSs. Countries may also choose to apply the derogation rule (e.g., articles 4, 11, and 12) for habitat types that cover more than three per cent of their European territory, allowing countries to be exempted from certain requirements under specific conditions. This could lead to prioritising restoration efforts, whereby certain forest habitats, despite

their ecological significance, are sidelined based on geographical prevalence. Parliament introduced both exemptions during negotiations [14], which the Council later approved. The substantial changes to the restoration regulation [8] suggest a significant dilution regarding its original intent and enforcement capacity. This will likely affect the regulation's impact and, more importantly, its efficacy in aligning with and implementing the goals and targets of the KM-GBF.

EU forest-related policies currently stand at a crossroads, where entrenched and conflicting policy objectives are, arguably, affecting forest use and management [33,34]. For example, the availability of suitable land for afforestation is limited due to competing land-use demands. This refers to the availability of suitable land for afforestation and the competition for land between different land uses, such as forests, agriculture, and urban development. This complexity can be exemplified by the Common Agricultural Policy (CAP), which inadvertently promotes agricultural expansion while improving agricultural productivity, potentially at the expense of afforestation measures. This dynamic emphasises some inconsistencies between the farmland-focused, climate change-focused, and protected area-focused goals of relevant EU policy instruments, such as the CAP, the restoration regulation, and the climate law [35]. Supporting this perspective, Rolo et al. [36] have demonstrated a positive correlation between forest coverage in a landscape and ecosystem services, both provisioning and regulating, in contrast to negative correlations observed with increased agricultural land use. This finding highlights the importance of achieving a balanced integration of policy objectives that do not compromise long-term biodiversity conservation and climate change mitigation.

These discrepancies have broader implications for the global biodiversity agenda and the KM-GBF. The amendments to the restoration regulation weaken the regulation's enforcement mechanism and reduce the ambition of the EU's restoration efforts, which may lead to a fragmented approach to forest restoration across EU MSs. The EU's incoherence and reduced ambition in forest restoration may affect global efforts to halt and reverse biodiversity loss. In other words, the EU's commitment to the KM-GBF, particularly targets related to sustainable forest management and ecosystem restoration, risks being compromised, which would have knock-on effects regarding global objectives. Unfortunately, with the restoration regulation being adopted, it is no longer possible to strengthen the legal and implementation framework to ensure binding commitments and EU MS accountability.

Conclusions

Despite some gaps in coverage, the KM-GBF and the restoration regulation are largely complementary. However, better alignment is needed between the KM-GBF, the restoration regulation, and other forest-relevant EU policy instruments. Considering the varied regional challenges and EU policy objectives, a more integrated policy approach is essential. The alignment between these EU frameworks would support a strategic consolidation of efforts towards forest conservation and restoration in Europe. In addition, it needs to be recognised that the efficacy of future forest measures has been significantly undermined by the EU's reduced regulatory ambitions, as seen in the amendments to the restoration regulation. This will ultimately limit the EU's ability to hold countries accountable and to meet the global biodiversity targets set out in the KM-GBF. It is, for this reason, imperative that the EU look beyond individual policy silos and that steps are taken to ensure that measures targeting forests are coherent and effective, accounting for divergent EU policy pathways and objectives.

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Appendix A

Goals of the Kunming-Montreal Global Biodiversity Framework.
GOAL A The integrity, connectivity and resilience of all ecosystems are maintained, enhanced, or restored, substantially increasing the area of natural ecosystems by 2050; Human induced extinction of known threatened species is halted, and by 2050, the extinction rate and risk of all species will be reduced tenfold, and the abundance of native wild species is increased to healthy and resilient levels; The genetic diversity within populations of wild and domesticated species is maintained, safeguarding their adaptive potential.
GOAL B Biodiversity is sustainably used and managed, and nature's contributions to people, including ecosystem functions and services, are valued, maintained and enhanced, with those currently in decline being restored, supporting the achievement of sustainable development for the benefit of present and future generations by 2050.
GOAL C The monetary and non-monetary benefits from the utilisation of genetic resources, digital sequence information on genetic resources, and traditional knowledge associated with genetic resources, as applicable, are shared fairly and equitably, including, as appropriate, with indigenous peoples and local communities, and substantially increased by 2050, while ensuring traditional knowledge associated with genetic resources is appropriately protected, thereby contributing to the conservation and sustainable use of biodiversity, in accordance with internationally agreed access and benefit-sharing instruments.
GOAL D Adequate means of implementation, including financial resources, capacity-building, technical and scientific cooperation, and access to and transfer of technology to fully implement the Kunming-Montreal global biodiversity framework are secured and equitably accessible to all Parties, especially developing countries, in particular the least developed countries and small island developing States, as well as countries with economies in transition, progressively closing the biodiversity finance gap of 700 billion dollars per year, and aligning financial flows with the Kunming-Montreal Global Biodiversity Framework and the 2050 Vision for Biodiversity.

Appendix B

Articles in the EU Regulation on Nature Restoration.
Article 1: Subject matter
Article 2: Geographical scope
Article 3: Definitions
Article 4: Restoration of terrestrial, coastal and freshwater ecosystems
Article 5: Restoration of marine ecosystems
Article 5a: Energy from renewable sources
Article 5b: National defence
Article 6: Restoration of urban ecosystems
Article 7: Restoration of the natural connectivity of rivers and natural functions of the related floodplains
Article 8: Restoration of pollinator populations
Article 9: Restoration of agricultural ecosystems
Article 10: Restoration of forest ecosystems
Article 10a: Planting of three billion additional trees
Article 11: Preparation of the national restoration plans
Article 12: Content of the national restoration plans
Article 13: Submission of the draft national restoration plan
Article 14: Assessment of the national restoration plans
Article 14a: Coordination of restoration measures in marine ecosystems
Article 15: Review of the national restoration plans
Article 17: Monitoring
Article 18: Reporting
Article 19: Amendment of Annexes
Article 20: Exercise of the delegation
Article 21: Committee procedure
Article 21a: Amendment to Regulation (EU) 2022/869
Article 22: Review
Article 22a: Temporary suspension
Article 23: Entry into force

Appendix C

Crosswalk between Forest-Relevant KM-GBF Targets against Forest-Relevant EU Policy Instruments

	KM-GBF Targets	Forest-Relevant EU Policy Instruments (Non-Exhaustive)
1. Reducing threats to biodiversity	Target 1: [. . .] bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030 [. . .].	• Regulation on Nature Restoration (2022/0195 (COD)). • Forest Strategy (COM(2021) 572 final). • Biodiversity Strategy for 2030 (COM(2020) 380 final). • Habitats and Birds Directive, including Natura 2000 (92/43/EEC and 79/409/EEC). • Soil Strategy (COM/2021/699 final). • Water Framework Directive (2000/60/EC). • EU Marine Strategy Framework Directive (2008/56/EC). • *Funding programmes* (e.g., LIFE, Horizon Europe, and European Maritime and Fisheries Fund).
	Target 2: Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration [. . .].	
	Target 3: Ensure and enable that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed [. . .].	
	Target 4: Ensure urgent management actions to halt human induced extinction of known threatened species and for the recovery and conservation of species [. . .].	
	Target 5: Ensure that the use, harvesting and trade of wild species is sustainable, safe and legal, preventing overexploitation, minimising impacts on non-target species and ecosystems, and reducing the risk of pathogen spillover, applying the ecosystem approach, while respecting and protecting customary sustainable use by indigenous peoples and local communities.	• Timber Regulation (995/2010) and Regulation on deforestation-free products (2023/1115). • Forest Law Enforcement, Governance and Trade (FLEGT) Regulation (2173/2005). • Phytosanitary regulation (2019/2072) • Protection of species of wild fauna and flora by regulating trade therein (338/97). • EU action plan against wildlife trafficking (COM/2022/581 final).
	Target 6: Eliminate, minimise, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services [. . .] reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent by 2030 [. . .].	• Invasive Alien Species Regulation (1143/2014)
	Target 7: Reduce pollution risks and the negative impact of pollution from all sources by 2030, to levels that are not harmful to biodiversity and ecosystem functions and services, considering cumulative effects, including: (a) by reducing excess nutrients lost to the environment by at least half, including through more efficient nutrient cycling and use; (b) by reducing the overall risk from pesticides and highly hazardous chemicals by at least half, including through integrated pest management, based on science, taking into account food security and livelihoods; and (c) by preventing, reducing, and working towards eliminating plastic pollution.	• Towards Zero Pollution for Air, Water and Soil (COM/2021/400 final). • Waste Framework Directive (2008/98/EC). • Environmental Liability Directive (2004/35/CE). • Single Use Plastics Directive (2019/904). • A Green Deal Industrial Plan for the Net-Zero Age (COM(2023) 62 final). • *Instruments on air quality and emissions* (e.g., Industrial Emission Directive (2010/75/EU), Ambient Air Quality and Cleaner Air Directive (2008/50/EC), and National Emission Ceilings Directive (2016/2284/EU)).
	Target 8: Minimise the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions, including through nature-based solutions and/or ecosystem-based approaches, while minimising negative and fostering positive impacts of climate action on biodiversity.	• European Green Deal (COM(2019) 640 final). • European Climate Law (2021/1119). • Fit for 55 package (COM(2021) 550 final) and associated EU legislation. • 2030 climate and energy framework (COM(2020) 562 final). • Land Use, Land Use Change and Forestry (LULUCF) (2023/839). • Renewable Energy Directive (2023/2413). • Climate Adaptation Strategy (COM(2021) 82 final).

	KM-GBF Targets	Forest-Relevant EU Policy Instruments (Non-Exhaustive)
2. Meeting people's needs through sustainable use and benefit-sharing	Target 9: Ensure that the management and use of wild species are sustainable, thereby providing social, economic and environmental benefits for people, especially those in vulnerable situations and those most dependent on biodiversity, including through sustainable biodiversity-based activities, products and services that enhance biodiversity, and protecting and encouraging customary sustainable use by indigenous peoples and local communities.	• Regulation on Nature Restoration (2022/0195 (COD)). • Biodiversity Strategy for 2030 (COM(2020) 380 final). • Habitats and Birds Directive, including Natura 2000 (92/43/EEC and 79/409/EEC). • Green Infrastructure Strategy (COM(2013) 0249 final) • Pollinators Initiative (COM(2023) 35 final). • Common Agricultural Policy (2021/2115, 2021/2116, and 2021/2117). • *See also instruments listed for targets 5 and 6*.
	Target 10: Ensure that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity, including through a substantial increase of the application of biodiversity friendly practices, such as sustainable intensification, agro-ecological and other innovative approaches, contributing to the resilience and long-term efficiency and productivity of these production systems, and to food security, conserving and restoring biodiversity and maintaining nature's contributions to people, including ecosystem functions and services.	• Regulation on Nature Restoration (2022/0195 (COD)). • Common Agricultural Policy (2021/2115, 2021/2116, and 2021/2117). • Farm to Fork Strategy (COM(2020) 381 final). • Forest Strategy (COM(2021) 572 final). • Biodiversity Strategy for 2030 (COM(2020) 380 final). • Water Framework Directive (2000/60/EC). • Bioeconomy Strategy (COM(2018) 673 final). • Natura 2000 Network (92/43/EEC and 79/409/EEC).
	Target 11: Restore, maintain and enhance nature's contributions to people, including ecosystem functions and services, such as the regulation of air, water and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature.	• Regulation on Nature Restoration (2022/0195 (COD)). • Biodiversity Strategy for 2030 (COM(2020) 380 final). • Green Infrastructure Strategy (COM(2013) 0249 final). • Climate Adaptation Strategy (COM(2021) 82 final). • Soil Strategy (COM/2021/699 final). • Common Agricultural Policy (2021/2115, 2021/2116, and 2021/2117). • Pollinators Initiative (COM(2023) 35 final). • Civil Protection Mechanism (2021/836). • European Climate Law (2021/1119). • Climate Adaptation Strategy (COM(2021) 82 final).
	Target 12: Significantly increase the area and quality, and connectivity of, access to, and benefits from green and blue spaces in urban and densely populated areas sustainably, by mainstreaming the conservation and sustainable use of biodiversity, and ensure biodiversity-inclusive urban planning, enhancing native biodiversity, ecological connectivity and integrity, and improving human health and well-being and connection to nature, and contributing to inclusive and sustainable urbanisation and to the provision of ecosystem functions and services.	• Regulation on Nature Restoration (2022/0195 (COD)). • Biodiversity Strategy for 2030 (COM(2020) 380 final). • Green Infrastructure Strategy (COM(2013) 0249 final). • Urban Agenda for the EU (Pact of Amsterdam). • Climate Adaptation Strategy (COM(2021) 82 final). • Environment Action Programme to 2030 (2022/591). • EU Cohesion Policy 2021–2027. • Covenant of Mayors for Climate & Energy.
	Target 13: Take effective legal, policy, administrative and capacity-building measures at all levels, as appropriate, to ensure the fair and equitable sharing of benefits that arise from the utilisation of genetic resources and from digital sequence information on genetic resources, as well as traditional knowledge associated with genetic resources, and facilitating appropriate access to genetic resources, and by 2030, facilitating a significant increase of the benefits shared, in accordance with applicable international access and benefit-sharing instruments.	• Access and Benefit Sharing (ABS) Regulation (511/2014). • Plant Reproductive Material (2018/848, new proposal: COM(2023) 414 final). • Forest reproductive material (1999/105/EC, new proposal: COM(2023) 415 final). • European Forest Genetic Resources Programme (FOREST EUROPE resolution S2). • Genetic Resources Strategy for Europe (GenRes Bridge project).

	KM-GBF Targets	Forest-Relevant EU Policy Instruments (Non-Exhaustive)
3. Tools and solutions for implementation and mainstreaming	Target 14: Ensure the full integration of biodiversity and its multiple values into policies, regulations, planning and development processes, poverty eradication strategies, strategic environmental assessments, environmental impact assessments and, as appropriate, national accounting, within and across all levels of government and across all sectors, in particular those with significant impacts on biodiversity, progressively aligning all relevant public and private activities, and fiscal and financial flows with the goals and targets of this framework.	• Biodiversity Strategy for 2030 (COM(2020) 380 final). • European Green Deal (COM(2019) 640 final). • Strategic Environmental Assessment (SEA) Directive (2001/42/EC). • Environmental Impact Assessment (EIA) Directive (2014/52/EU). • Taxonomy Regulation (2020/852). • Habitats and Birds Directive, including Natura 2000 (92/43/EEC and 79/409/EEC). • Land Use, Land Use Change and Forestry (LULUCF) (2023/839).
	Target 15: Take legal, administrative or policy measures to encourage and enable business, and in particular to [. . .] disclose their risks, dependencies and impacts on biodiversity [. . .] promote sustainable consumption patterns [. . .] compliance with access and benefit-sharing regulations and measures [. . .].	• Taxonomy Regulation (2020/852). • Sustainable Finance Disclosure Regulation (2022/1288). • Non-Financial Reporting Directive (2014/95/EU). • Corporate Sustainability Reporting Directive (2022/2464). • Circular Economy Action Plan (COM(2020)98 final). • Product Environmental Footprint (C(2021) 9332 final). • Action Plan for Nature, People and the Economy. • Eco-Management and Audit Scheme (2018/2026).
	Target 16: Ensure that people are encouraged and enabled to make sustainable consumption choices, including by establishing supportive policy, legislative or regulatory frameworks, improving education and access to relevant and accurate information and alternatives, and by 2030, reduce the global footprint of consumption in an equitable manner, including through halving global food waste, significantly reducing overconsumption and substantially reducing waste generation, in order for all people to live well in harmony with Mother Earth.	• Circular Economy Action Plan (COM(2020)98 final). • Farm to Fork Strategy (COM(2020) 381 final). • Waste Framework Directive (2008/98/EC). • Single Use Plastics Directive (2019/904). • Ecodesign Directive (2009/125/EC). • Energy Labelling Directive (2017/1369). • Green Public Procurement (COM(2008) 400 final). • Eco-Management and Audit Scheme (2018/2026). • Consumer Rights Directive (2011/83/EU). • Bioeconomy Strategy (COM(2018) 673 final). • Strategy on Green Finance (COM(2021) 390 final).
	Target 18: Identify by 2025, and eliminate, phase out or reform incentives, including subsidies, harmful for biodiversity, in a proportionate, just, fair, effective and equitable way, while substantially and progressively reducing them by at least $500 billion per year by 2030, starting with the most harmful incentives, and scale up positive incentives for the conservation and sustainable use of biodiversity.	• Biodiversity Strategy for 2030 (COM(2020) 380 final). • Taxonomy Regulation (2020/852). • Strategy on Green Finance (COM(2021) 390 final).
	Target 21: Ensure that the best available data, information and knowledge are accessible to decision makers, practitioners and the public to guide effective and equitable governance, integrated and participatory management of biodiversity, and to strengthen communication, awareness-raising, education, monitoring, research and knowledge management and, also in this context, traditional knowledge, innovations, practices and technologies of indigenous peoples and local communities should only be accessed with their free, prior and informed consent, in accordance with national legislation.	• Regulation on Nature Restoration (2022/0195 (COD)). • Forest Strategy (COM(2021) 572 final). • Monitoring framework for resilient European forests (Proposal: COM(2023)728). • INSPIRE Directive (2007/2/EC).

References

1. CBD. *The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets*; UNEP/CBD/COP/DEC/X/2; Convention on Biological Diversity: Nagoya, Japan, 2010.
2. Buchanan, G.M.; Butchart, S.H.M.; Chandler, G.; Gregory, R.D. Assessment of National-Level Progress towards Elements of the Aichi Biodiversity Targets. *Ecol. Indic.* **2020**, *116*, 106497. [CrossRef]
3. CBD. *Kunming-Montreal Global Biodiversity Framework*; CBD/COP/DEC/15/4; Convention on Biological Diversity: Montreal, QC, Canada, 2022.
4. Henriques, S.; Böhm, M.; Collen, B.; Luedtke, J.; Hoffmann, M.; Hilton-Taylor, C.; Cardoso, P.; Butchart, S.H.M.; Freeman, R. Accelerating the Monitoring of Global Biodiversity: Revisiting the Sampled Approach to Generating Red List Indices. *Conserv. Lett.* **2020**, *13*, e12703. [CrossRef]
5. Pereira, H.M.; Rosa, I.M.D.; Martins, I.S.; Kim, H.; Leadley, P.; Popp, A.; Van Vuuren, D.P.; Hurtt, G.; Anthoni, P.; Arneth, A.; et al. Global Trends in Biodiversity and Ecosystem Services from 1900 to 2050. *bioRxiv* **2020**. [CrossRef]
6. Hughes, C.; Grumbine, R.E. The Kunming-Montreal Global Biodiversity Framework: What It Does and Does Not Do, and How to Improve It. *Front. Environ. Sci.* **2023**, *11*, 1281536. [CrossRef]
7. Venegas-Li, R.; Grantham, H.S.; Rainey, H.; Diment, A.; Tizard, R.; Watson, J.E.M. An Operational Methodology to Identify Critical Ecosystem Areas to Help Nations Achieve the Kunming-Montreal Global Biodiversity Framework. *bioRxiv* **2023**. [CrossRef]
8. EC. *Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration*; European Commission: Brussels, Belgium, 2022.
9. EC. *EU Biodiversity Strategy for 2030: Bringing Nature Back into Our Lives*; COM (2020) 380 Final; European Commission: Brussels, Belgium, 2020.
10. Council of the EU. *Nature Restoration: Council and Parliament Reach Agreement on New Rules to Restore and Preserve Degraded Habitats in the EU*; General Secretariat of the Council: Brussels, Belgium, 2023.
11. EC. *The European Green Deal*; COM (2019) 640 Final; European Commission: Brussels, Belgium, 2019.
12. CBD. *Monitoring Framework for the Kunming-Montreal Global Biodiversity Framework*; CBD/COP/DEC/15/5; Convention on Biological Diversity: Montreal, QC, Canada, 2022.
13. Xu, H.; Cao, Y.; Yu, D.; Cao, M.; He, Y.; Gill, M.; Pereira, H.M. Ensuring Effective Implementation of the Post-2020 Global Biodiversity Targets. *Nat. Ecol. Evol.* **2021**, *5*, 411–418. [CrossRef] [PubMed]
14. Council of the EU. *Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration*; General Secretariat of the Council: Brussels, Belgium, 2023.
15. Bowen, G.A. Document Analysis as a Qualitative Research Method. *Qual. Res. J.* **2009**, *9*, 27–40. [CrossRef]
16. Elo, S.; Kääriäinen, M.; Kanste, O.; Pölkki, T.; Utriainen, K.; Kyngäs, H. Qualitative Content Analysis: A Focus on Trustworthiness. *SAGE Open* **2014**, *4*, 2158244014522633. [CrossRef]
17. Glaser, B.G.; Strauss, A. *The Discovery of Grounded Theory: Strategies of Qualitative Research*; Aldine: New York, NY, USA, 1967.
18. Strauss, A.; Corbin, J. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*; SAGE Publications: Newbury Park, CA, USA, 1990.
19. Giuntoli, J.; Barredo, J.I.; Avitabile, V.; Camia, A.; Cazzaniga, N.E.; Grassi, G.; Jasinevičius, G.; Jonsson, R.; Marelli, L.; Robert, N.; et al. The Quest for Sustainable Forest Bioenergy: Win-Win Solutions for Climate and Biodiversity. *Renew. Sustain. Energy Rev.* **2022**, *159*, 112180. [CrossRef]
20. Soimakallio, S.; Kalliokoski, T.; Lehtonen, A.; Salminen, O. On the Trade-Offs and Synergies between Forest Carbon Sequestration and Substitution. *Mitig. Adapt. Strateg. Glob. Chang.* **2021**, *26*, 4. [CrossRef]
21. Soimakallio, S.; Böttcher, H.; Niemi, J.; Mosley, F.; Turunen, S.; Hennenberg, K.J.; Reise, J.; Fehrenbach, H. Closing an Open Balance: The Impact of Increased Tree Harvest on Forest Carbon. *GCB Bioenergy* **2022**, *14*, 989–1000. [CrossRef]
22. Booth, M.S. *Burning up the Carbon Sink: How the EU's Forest Biomass Policy Undermines Climate Mitigation, and How It Can Be Reformed*; Partnership for Policy Integrity: Pelham, MA, USA, 2022.
23. Santangeli, A.; Di Minin, E.; Toivonen, T.; Pogson, M.; Hastings, A.; Smith, P.; Moilanen, A. Synergies and Trade-offs between Renewable Energy Expansion and Biodiversity Conservation—A Cross-national Multifactor Analysis. *GCB Bioenergy* **2016**, *8*, 1191–1200. [CrossRef]
24. Wüstemann, H.; Bonn, A.; Albert, C.; Bertram, C.; Biber-Freudenberger, L.; Dehnhardt, A.; Döring, R.; Elsasser, P.; Hartje, V.; Mehl, D.; et al. Synergies and Trade-Offs between Nature Conservation and Climate Policy: Insights from the "Natural Capital Germany—TEEB DE" Study. *Ecosyst. Serv.* **2017**, *24*, 187–199. [CrossRef]
25. Stubenrauch, J.; Garske, B. Forest Protection in the EU's Renewable Energy Directive and Nature Conservation Legislation in Light of the Climate and Biodiversity Crisis—Identifying Legal Shortcomings and Solutions. *For. Policy Econ.* **2023**, *153*, 102996. [CrossRef]
26. Münnich, M.; Elofsson, K. Is Forest Carbon Sequestration at the Expense of Bioenergy and Forest Products Cost-Efficient in EU Climate Policy to 2050? *J. For. Econ.* **2017**, *24*, 82–105.
27. Pingoud, K.; Ekholm, T.; Sievänen, R.; Huuskonen, S.; Hynynen, J. Trade-Offs between Forest Carbon Stocks and Harvests in a Steady State—A Multi-Criteria Analysis. *J. Environ. Manag.* **2018**, *210*, 96–103. [CrossRef] [PubMed]

28. Biber, P.; Felton, A.; Nieuwenhuis, M.; Lindbladh, M.; Black, K.; Bahýl', J.; Bingöl, Ö.; Borges, J.G.; Botequim, B.; Brukas, V.; et al. Forest Biodiversity, Carbon Sequestration, and Wood Production: Modeling Synergies and Trade-Offs for Ten Forest Landscapes Across Europe. *Front. Ecol. Evol.* **2020**, *8*, 547696. [CrossRef]
29. Blattert, C.; Mönkkönen, M.; Burgas, D.; Di Fulvio, F.; Toraño Caicoya, A.; Vergarechea, M.; Klein, J.; Hartikainen, M.; Antón-Fernández, C.; Astrup, R.; et al. Climate Targets in European Timber-Producing Countries Conflict with Goals on Forest Ecosystem Services and Biodiversity. *Commun. Earth Environ.* **2023**, *4*, 119. [CrossRef]
30. Sabatini, F.M.; De Andrade, R.B.; Paillet, Y.; Ódor, P.; Bouget, C.; Campagnaro, T.; Gosselin, F.; Janssen, P.; Mattioli, W.; Nascimbene, J.; et al. Trade-Offs between Carbon Stocks and Biodiversity in European Temperate Forests. *Glob. Change Biol* **2019**, *25*, 536–548. [CrossRef]
31. Aggestam, F.; Konczal, A.; Sotirov, M.; Wallin, I.; Paillet, Y.; Spinelli, R.; Lindner, M.; Derks, J.; Hanewinkel, M.; Winkel, G. Can Nature Conservation and Wood Production Be Reconciled in Managed Forests? A Review of Driving Factors for Integrated Forest Management in Europe. *J. Environ. Manag.* **2020**, *268*, 110670. [CrossRef]
32. Konczal, A.A.; Derks, J.; De Koning, J.H.C.; Winkel, G. Integrating Nature Conservation Measures in European Forest Management—An Exploratory Study of Barriers and Drivers in 9 European Countries. *J. Environ. Manag.* **2023**, *325*, 116619. [CrossRef] [PubMed]
33. Aggestam, F.; Pülzl, H. Downloading Europe: A Regional Comparison in the Uptake of the EU Forest Action Plan. *Sustainability* **2020**, *12*, 3999. [CrossRef]
34. Aggestam, F.; Giurca, A. The Art of the "Green" Deal: Policy Pathways for the EU Forest Strategy. *For. Policy Econ.* **2021**, *128*, 102456. [CrossRef]
35. Felix, L.; Houet, T.; Verburg, P.H. Mapping Biodiversity and Ecosystem Service Trade-Offs and Synergies of Agricultural Change Trajectories in Europe. *Environ. Sci. Policy* **2022**, *136*, 387–399. [CrossRef]
36. Rolo, V.; Roces-Diaz, J.V.; Torralba, M.; Kay, S.; Fagerholm, N.; Aviron, S.; Burgess, P.; Crous-Duran, J.; Ferreiro-Dominguez, N.; Graves, A.; et al. Mixtures of Forest and Agroforestry Alleviate Trade-Offs between Ecosystem Services in European Rural Landscapes. *Ecosyst. Serv.* **2021**, *50*, 101318. [CrossRef]

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Unraveling Power Relations: An Analytical Matrix for Territorial Brands

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Abstract: Cities are complex entities, reflecting an intricate system of relationships intertwined over time, development processes, and territorial planning, sustainability and management. Within this network of interactions among people and territories, the presence of territorial brands stands out. The central research question focuses on how the construction of an analytical framework can reveal intertwined power relations in a territory represented by territorial brands. The aim of this study is to develop and apply a unique analytical matrix, designed to highlight, and analyze the intricate power relations in a territory defined by territorial brands. Urban-geography and cultural studies approaches were incorporated into the case study methodology. Findings from the study revealed multiple layers of intertwined power relations in the territory, where territorial brands play the role of legitimizing mechanisms for the discourses of social actors in the produced territory. The conclusion emphasizes the effectiveness of the "territorial brand in regional development" matrix (TBRD) in highlighting the layers of power relations, as well as highlighting the contradictions between the local and the global in the space produced and represented by territorial brands. This study not only contributes to more effective territorial management but also enhances the understanding of the interaction between brand and territory, emphasizing the influence of these dynamics on the configuration and representation of urban space, including sustainability issues and their associated challenges.

Keywords: territorial brand; regional development; analytical matrix; urban and cultural geography; power relations; cultural studies; social actors; territorial representation; place, urban studies; sustainability

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1. Introduction

Across time and space, territorial brands influence regional development, people, territory, and the environment, playing a crucial role in the formation of power structures. The presence of these brands creates a complex network of symbolic values, explored in cultural studies [1–3] and urban-territorial studies [4,5]. This multidisciplinary scenario highlights the lived territory [6] as a context for in-depth analysis, integrating the territorial brands [7–9]. Symbolic-cultural values and beliefs intersect with the urban imaginary [10], and shaping the space [5,11]. Perspectives on urban-territorial contexts, development processes, planning, and territorial management are intrinsically linked to territorial brands, directly or indirectly. Inquiry into the motivations behind these brands and their role in social interventions, as well as investigations into power structures and relations, is a crucial point. Thus, the construction of an analytical framework emerges as a tool capable of examining the relations that traverse territories, unveiling how and why these relations are translated into dynamics such as brands.

The study is focused on exploring central and interrelated elements present in the territorial brand. It is based on the premise that the study on "territorial brand as a cultural product within the scope of regional development" [9], by constituting an analytical framework, investigates the brand itself and how the territory is reflected in this brand.

Commencing with contested and strategically articulated identities, the analysis encompasses intertwined relations in a collectively produced, consumed, and experienced space. It involves mechanisms that legitimize dual territoriality (brand and social actors),

utilizing discourses present in singular brands (the territorial ones). This context encompasses symbolic uses and appropriations of the territory, intersected by various power relations present in the simplified dynamics of product brands.

Territory, as per Lefebvre [12], is a social and collective product, and the application of marketing dynamics requires adjustments to the territorial context. This study proposes a cultural-territorial analysis where culture is understood as a structure of symbolic power [1,13] that delimits the territory through the power relations of social actors [6], extending beyond its geographic delineation. In this context, there is a contestation for space related to the value and construction of meanings about the place [4,14–16], including the urban regeneration of historic centers, the territorial planning of cities and regions, as well as images of the territory [17].

Therefore, a question emerges in this study: how can the construction of an analytical matrix highlight overlaid power relations in a territory represented by territorial brands? This inquiry arises from the need to fill gaps in the study of relationships between brands and territories [7,9,18], especially in the analysis of territorial brands from the perspective of regional development. Thus, this research contributes to advancing interdisciplinary studies on urban studies, place branding, regional territorial development, communication, international relations, economics, territorial public policies, urban transformations, territorial management, territorial-cultural identity, urban and cultural geography, and related discussions.

Consequently, this study proposes to develop and apply an analytical framework, named "territorial brand in regional development" (TBRD), aimed at analyzing power relations in a territory represented by territorial brands. Conceived as an innovative tool, the TBRD assists in interpreting the different layers of power present in territories. It considers elements such as contested identities, legitimization mechanisms, and the interaction between brands and social actors, including the environmental context. By employing a cultural-territorial approach, this matrix aids in a deeper understanding of underlying dynamics, providing significant insights for the analysis of power relations in urban and regional contexts. It involves a debate that extends to the comprehension of relationships between brands and territories and the contradictory processes between the local and the global. In this dynamic, pacts and disputes related to public policies [19], power relations embedded in territorial brands [9], the production of a lived territory [6], and urban imaginaries [10] are identified. Hence, it is a comprehensive discussion that integrates and expands urban-territorial theories, place branding, and regional territorial development.

The justifications for this research include evidence from studies on brands and territories, positioning territorial brands in regional development as cultural artifacts and mechanisms for legitimizing the discourses of social actors [9]. These pieces of evidence strengthen and play a role in maintaining hegemonic culture [1], creating planned and intentional urban imaginaries [10]. It is argued that the contradictions of territories [4] under the approach of territorial brands in regional development [9] reveal hidden power relations [6] in the territory, discourses of social actors, and competitiveness among territories [7], placing the city on a global map of places [20]. Various territorial brands implemented since 1980 [9] share urban-cultural components, driving competitive and collaborative practices among cities, regions, and countries. It is assumed that what happens in the territory (internal and external forces) influences the territorial brand (including its creation or non-creation), and the discourse of the territorial brand influences territorial dynamics, production, and reputation. Thus, it is believed that the TBRD matrix, as an analytical model, contributes to investigating the relationships between brands and territories on multiple scales and dimensions, extending to various contemporary realities.

The first part of the article introduces the themes, objectives, problematization, and justifications of the research. Following this, it progresses to the state of the art and the theoretical framework adopted based on the studies of Almeida [9], who coined the concept of "territorial brand in regional development," elucidating each element that comprised the quadrants of the TBRD matrix. The proposed matrix also addresses the production

process of the territorial brand, relating it to the territorial context of the empirically investigated cases. The subsequent sections delve into the research methodology, data analysis, functionality, and applicability of the mentioned matrix, leading to the main findings and discussions. Finally, the study's conclusion is summarized.

2. Theoretical Framework

2.1. Territorial Brands in the Scope of Regional Development

Grounded in the concept proposed by Almeida [9], the theoretical framework of this study was chosen for establishing a direct connection with theories of regional development. Specifically, this concept frames the territorial brand as a cultural product that plays a crucial role in legitimizing the discourses of social actors within the territorial and regional context. Furthermore, it stands out for its uniqueness in addressing the intersection between territorial brand and theories of regional development.

The understanding of a "territorial brand in the scope of regional development" encompasses the creation of symbolic-territorial value through an articulation among social actors, marked by pacts and conflicts related to the diversity of territorial identities and their role as territorial assets. It is a concept that transcends capitalist logic by entering the realm of regional development, establishing significant symbolic connections with territories and regions. These connections refer to narratives about the territory and the strategies adopted for the construction of this specific type of brand [9].

According to Almeida's [9] emphasis, a territorial brand represents a multifaceted concept, encompassing an intentionally organized articulation between discursive, verbal, and visual elements. Additionally, it manifests in conflicts and pacts between territorial identities and hegemonic cultures [21,22]. This dynamic is understood as mechanisms or urban instruments involved in the production of the lived territory [6]. It is a theoretical approach that provides a solid foundation for the analysis of the relationships between territorial brands and regional development, highlighting the importance of the brand as an intrinsic element to the production of the territory and the construction of territorial identities.

2.2. Territorial Brand in Regional Development Matrix: TBRD

The comprehension of the territorial brand matrix in regional development, referred to as TBRD, arises from three distinct movements within the territory: the territory of brands, brands in the territory, and territory as a brand [18]. The first two movements delve into the concept of potentiation, investigating whether brands enhance territories or if it is the territories that enhance brands. While each separately addresses the brand and the territory, they reveal correlations between these two thematic elements.

The third movement proposes contemplation on the territory as a brand, distinct, however, from the marketing brand [18]. When constructing a territorial brand, strategies are developed, mobilizing a complex network of social actors. In this sense, territorial brands, in the context of regional development, are intrinsically linked to power relations and the construction of strategic narratives about territories, articulating values and beliefs [9] involved in the utilization and appropriation of the territory [4]. These narratives do not evolve organically over time but are planned according to the interests of social actors in relation to the territory they inhabit.

To comprehend the territorial brand from the perspective of regional and territorial development, it is essential to consider not only the tangibility of the territory but also its symbolic aspects [3,23], the spaces of articulation [24], and the diverse set of social actors [25,26]. In this context, the territorial brand transcends economic development, incorporating more comprehensive concepts. Almeida [9,27] emphasizes that creating a territorial brand implies an awareness of the complexity of three strategic processes: productive, creative, and strategic. The approach to the territorial brand highlights four macro elements: (1) brand, (2) territory, (3) strategic articulation, and (4) territorialities (social actors and the brand itself).

2.2.1. Brand

The concept of a brand encompasses any perceivable sign, whether visual or verbal [28]. Its fundamental functions include manufacturer identification, product quality validation [28], the construction of symbolic values [29], interaction with the consumer [30], and fluidity in the discourses of social actors [9]. It is important to note that the logo is just one facet of the brand, serving the role of graphically representing it [9].

A brand is composed of various elements that characterize it visually, such as colors, fonts, patterns, slogans, and a logo. Without these elements, the brand does not become perceptible, compromising the construction of its identity [31]. The brand identity is crafted by strategists, directing its image to consumers, and facilitating the encoding and decoding of specific messages [32], even when the act of consumption is not explicitly manifested [18].

For a brand to be recognized, strategies are adopted to make it familiar to the consumer, intending to stimulate consumption [33]. The brand's touchpoints represent the means of interaction with the consumer, encompassing aspects such as social media, packaging, website, price, and business cards [31]. The territoriality of the brand is linked to its power based on a symbolic arsenal [18], constructed under a planned visual and verbal system [34].

2.2.2. Strategic Connections

Strategic articulation represents an intentional maneuver that influences the worldview of social actors, impacting both the dynamics of the territory and within it [27]. This type of articulation is intrinsically linked to the interests of social actors in the production of the territory [4], and the brand plays a fundamental role in this process. Considering the brand as a cultural artifact [9], it draws upon hegemonic culture [1] to perpetuate the discourse of hegemony [35], exerting influence on the use and appropriation of the territory [4]. It is emphasized that culture has a political aspect that strategically contributes to the formation and transmission of a specific vision of the city [36] and its territories.

The decision to associate (or not) a brand with a territory also constitutes a strategy employed by social actors. This decision is far from a trivial discourse, as it transcends mere advertising or marketing endeavors [30], thereby rendering the brand ephemeral or temporary in nature [9]. The presence of territorial identities [23] and a discourse accepted by the diversity of social actors, or one that is naturalized within the territory, are intrinsic characteristics of territorial brands. Frequently, this discourse can engender pacts, disputes, or conflicts within the territory [9] across various geographical and socio-spatial scales.

Moreover, territorial brands are strategically embedded in the creative economy, being regarded as cultural alternatives for the transformation of urban space, as exemplified in the regeneration of historical city centers [37]. The strategic articulation aims at promoting the image of a territory, irrespective of its geographical scale. If, for instance, a city seeks cultural recognition, the brand will be intricately linked to cultural events, historical heritage, and unique artistic expressions of the city. It may also encompass the organization of annual festivals, support for local artists, and the incorporation of these cultural elements into the visual identity of the city.

2.2.3. Territory

According to Raffestin [6], territory is a space delimited by power relations among social actors, whether established or constantly under construction. Additionally, the territory is considered a conducive space for strategic articulations [24]. Evolving over time, the interests of social actors in the territory impact the production, use, and appropriation of this space [4,23]. Based on beliefs, the creation of narratives about territories [38] generates mental messages [31] transmitted through various languages, images, and representations. These narratives play a crucial role in building the territory's reputation [9], contributing to the formation of a symbolic-territorial market [18].

2.2.4. Territorialities of Social Actors and Territorial Brands

The territorialities associated with the territorial brand transcend the typical circulation and scope of market brands, also incorporating the territorialities of social actors. They encompass identities, tourist attractions, cultural aspects, and the physical structure of the territory. This realm of symbolic-territorial consumption [9] empowers the territorial brand, being intrinsically related to the use and appropriation of the territory [4,23]. It results from how people experience and take ownership of this produced space [6].

One way to quantify the territorialities of the territorial brand is through urban rankings, which generate a reputation for the territory – whether positive or negative. To enable the discourse of the brands, a symbolic arsenal is elaborated specifically for each brand [18]. This arsenal is anchored in a set of values, myths, and ideas formulated by strategists, involving persuasive skills, and encompassing elements such as infrastructure and a sense of belonging [3]. By articulating ideas, possibilities, and meanings, combining them with narratives (emotional and/or rational) and sensory experiences, the message contained in the brand is potentiated, allowing its role to reach a more complex level.

3. Methodology

3.1. Method

The methodology employed in this study follows Yin's [38] guidelines for the case study method and utilizes an integrated qualitative approach, combining elements from cultural studies and urban geography. A case study allows for a comparative and in-depth exploration of power dynamics in different contexts, even though it focuses on a single case. The research is grounded in a profound and holistic understanding of territorial brands, considering their recurrence since the 1980s. Thus, the methodology aids in unveiling the multiple layers of influence and interprets the complex power relations in a comprehensive manner.

The integration of the cultural studies approach allows for a profound analysis of the symbolic and discursive representations associated with each territorial brand, while the perspective of urban geography contributes to a comprehensive understanding of territorial dynamics. Conducted iteratively, the construction of the proposed analytical matrix incorporates four key elements identified in the theoretical framework: brand, territory, strategic articulations, and dual territorialities (social actors and brand). These elements were extracted from Almeida's [9] study, which considers territorial brands as cultural artifacts in regional development, embedding culture as a power structure. The matrix was designed to capture and organize macro and micro variables reflecting the diverse manifestations of power in the territory, encompassing both visible and symbolic dimensions of territorial brands.

3.2. Research Phases

The research unfolded through six phases, following Yin's [38] guidelines, which focus on specific aspects of structuring and developing the investigated case study.

(1) Definition of Conceptual-Theoretical Structure: In this initial phase, we mapped relevant literature and outlined fundamental propositions that guided the research.
(2) Case Planning: The second phase involved detailed planning of the case, including the selection of units of analysis, definition of methods for data collection and analysis, development of the research protocol, and establishment of means for effective study control.
(3) Pilot Test: The third phase encompassed conducting a pilot test to assess the application of procedures, verify the quality of collected data, and make necessary adjustments to the process.
(4) Data Collection and Recording: The fourth phase focused on executing data collection according to the established protocol, recording pertinent information for subsequent analysis.

(5) Data Analysis: The fifth phase was dedicated to a meticulous analysis of the collected data, applying the TBRD matrix to comprehend the dynamics and relationships present in the investigated case.
(6) Research Report Generation: In the final phase, we crafted the research report, documenting obtained data, outlining theoretical implications, and reviewing the methodological structure to facilitate potential study replicabilities.

3.3. Data Collection

This study employed mixed qualitative techniques for data collection, incorporating document analysis, consultation of official city websites, semi-structured interviews, and direct observation. Interviews were conducted with representatives from various sectors of the social actors involved in territorial practices related to brands, providing crucial qualitative insights for the research.

Data were collected in the city of Porto Alegre, Brazil, chosen due to the presence of a set of territorial brands competing for different representations of the city.

3.3.1. Brand Selection

The choice of Porto Alegre as the focus of this research was carefully considered, considering its historical context, the productive process of its territorial brands, and the strategies employed over time. As the capital, Porto Alegre developed a distinctive territorial brand aimed at differentiating its identity from that of the state. A detailed analysis of this brand is incorporated into the application of the proposed analytical matrix, allowing an understanding of the power relations between brands and territories.

3.3.2. Sources of Evidence

Various sources of evidence were utilized in this study, including:

- Territorial brand of city (logo and visual materials publicly available).
- Press releases (published in newspapers and in the written, spoken and digital press).
- Semi-structured interviews with two representatives of the local government (mayor and city hall communications coordinator, both active at the time the city's brand was created) and the agency responsible for creating the brand (2 designers who created the aforementioned brand were interviewed).
- Facebook and Instagram pages of cities investigated.
- Official city website Porto Alegre.
- Historical-territorial context of Porto Alegre.
- Triad of processes (productive, strategic, and creative) of territorial brands.

The cited sources were chosen for their public accessibility and their provision of information for each of the four axes of the MTnoDR matrix (TBRD in English translation), which specifically analyzes the power structure of territorial brands. This way, there is a distinction between place branding (market-focused brand) and territorial brand (development-focused brand).

3.4. Data Analysis Procedures

The data analysis was conducted systematically, employing the analytical matrix as a tool for the categorization and interpretation of territorial brands. A triangulation of methods and data sources was adopted to ensure the validity and reliability of the results.

Throughout the analysis process, a methodological protocol anchored in a set of guiding questions derived from regional development theories was utilized. These questions examined the categories of the four macro quadrants or axes of the TBRD matrix, establishing triangulation between them. The investigation delved into the power relations present in territories with territorial brands, incorporating perspectives from territorial-regional development, cultural studies, and urban geography.

The research emphasizes that in formulating the matrix, there is no recognition of an initial or final moment in this process, nor is there a hierarchy among the quadrants. Like a

circuit, the format of the quadrants adopts a dynamic of overlap between macro and micro, depending on the power structure that the brand sustains.

3.5. Research Period

The research development took place from January 2019 to January 2024, delving into theories related to territorial brand.

4. Proposal and Functionality of the TBRD Analytical Matrix

The TBRD matrix articulates four central elements, as outlined in Almeida's concept [9], arranged in quadrants or axes. This structure allows for the individual analysis (1 quadrant) or combined analysis (four quadrants) of a specific reality as a cultural artifact of the territory. Within the matrix context, the patterns of the "brand–territory–regional development" triad are investigated concerning socio-spatial and symbolic organization, examining the processes (productive, strategic, and creative) that lead a territory to being identified by a territorial brand. According to Feijó-de-Almeida [27], these brands also generate a representation and reputation for territories through a web of relationships that make them more competitive.

This proposal goes beyond merely describing the presence or absence of a brand in a specific space. The TBRD matrix enables more in-depth analyses, revealing layers of power relations in the territory, interwoven within a territorial brand, or highlighting these layers in the evolution or conflict among the social actors who create and deactivate them, activating other brands in their place. Each quadrant of the TBRD matrix also presents a set of micro quadrants, allowing for a detailed analysis of the relationships between brands and territory (Figure 1).

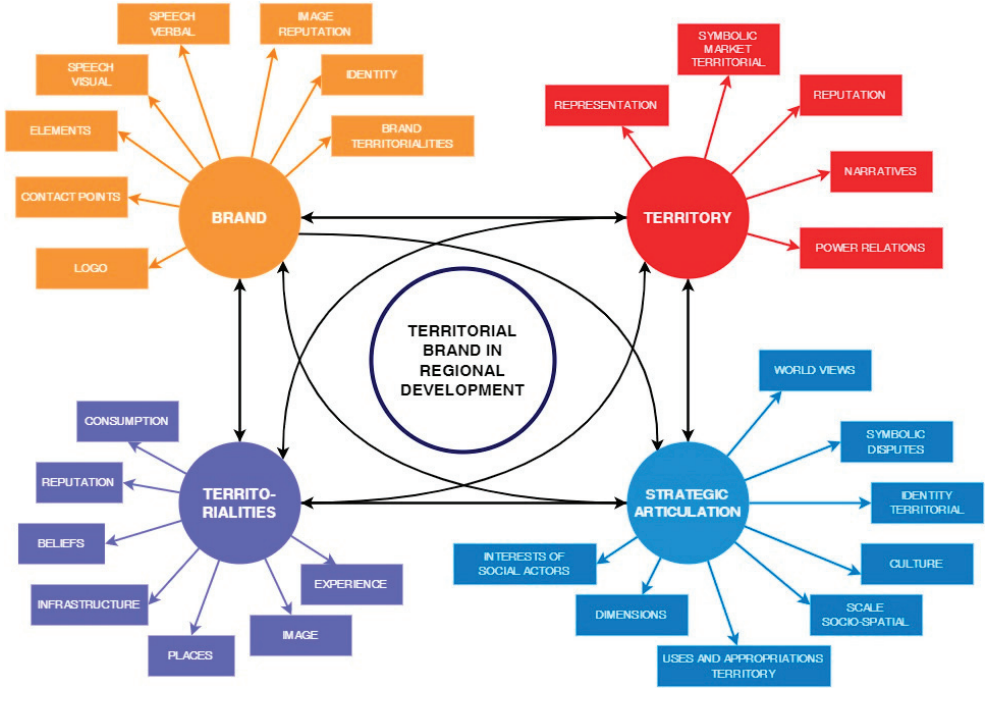


Figure 1. Methodological matrix of territorial brand in regional development – TBRD. Source: developed by the Author based on Almeida's study [9].

Thus, each quadrant depicted in Figure 1 includes between six and eight variables, referred to as micro quadrants, whose function is to unfold analytically the four macro quadrants of the TBRD matrix: brand, territory, strategic articulations, and territorialities. Therefore, the analytical matrix TBRD, developed based on Almeida's concept [9], proves to be a robust tool for the analysis of territorial brands considering regional development theories.

4.1. Applicability of the TBRD Matrix

As highlighted by Almeida [9] (p.186), "The study of territorial brands allows us to interpret the dynamics of territories, their actors, strategies, uses, and (re)meanings, contributing to understanding the productive process of brands in the context of territorial and regional development." Thus, the application of the TBRD matrix is crucial to deepen the analysis of the territorial brand of Porto Alegre Multicity, unraveling its complexities through a specific analytical approach.

Structured in quadrants, macros, and micros, the TBRD matrix emerges as a tool capable of capturing territorial dynamics, agreements, disputes, and the intricate power relations embedded in the production of the territory. In the context of territorial brands in regional development, it is essential to understand that, beyond distinctive signs, brands also create an image of power, or more precisely, the power of dominant actors [6].

In this sense, the TBRD matrix not only analyzes brands as isolated elements but contextualizes them within a complex network of power relations, absorbing the discourses of the social actors involved. It goes beyond the surface, unfolding layers of overlapping power relations, allowing for a deeper understanding of the mechanisms of power legitimation present in territorial brands. By exploring the territorial brand Porto Alegre Multicity with the TBRD Matrix, we seek to unveil how this brand becomes an intricate mechanism of power legitimation, traversed by discourses of social actors, agreements, disputes, and notably, a dual territoriality composed both by the brands and the actors themselves. This analytical approach provides a more holistic understanding of regional and territorial dynamics, highlighting the inherent complexity in the intersection between brands and power in regional-development processes.

4.2. Porto Alegre Brand and City

The practical application of the TBRD Matrix in the city of Porto Alegre, focusing on the Porto Alegre Multicity brand (Figure 2), provided an in-depth analysis of the complex power relations engendered in this context.



Figure 2. Porto Alegre Multicity Brand. Source: Almeida [9].

The brand was conceived between 2012 and 2013, capitalizing on the global visibility of the 2014 FIFA World Cup, held in Porto Alegre, Brazil. The goal was to internationalize the territorialities of the brand, seeking acceptance not only locally but also among international social actors. The study pertains to the timeframe during which the city's brand was conceived, spanning from 2012 to 2013, capitalizing on the global visibility of the 2014 FIFA World Cup. It's noteworthy that the brand wasn't devised solely for the 2014 World Cup but rather to embody the ideology of its creators. However, by 2016, the brand began to wane in influence due to a lack of comprehension among public officials regarding

its management, which extends beyond mere logo usage. Hence, the study focuses on this specific timeframe due to the shifts and challenges encountered by the brand during this period.

In an attempt by the local public authorities to gain acceptance from various social actors, the private sector, and civil society, the territorialities of the brand evolved from a local to an international scope. Thus, the visual-verbal discourse of the brand was grounded in the ethnic plurality that contributed to the formation of the city. The ensemble of social actors who created the brand used the concept of multiculturalism in the slogan, referring to the multiple ethnicities present in the Porto Alegre territory, deviating from Hall's [3] concept of multiculturalism.

The graphic elements of the brand referenced various parts of the city, particularly the historically and touristically central zones such as Parque Farroupilha (Redenção), Usina do Gasômetro, Fundação Iberê Camargo, Mercado Público, Estátua do Laçador, and the waterfront of the Guaíba River. Additionally, the brand's logo and its advertising campaign glorified these locations situated in the central areas of the city. Furthermore, the brand's image conveyed the plurality of territorial identities, distancing itself from the hegemonic Gaucho identity, and establishing connections beyond the territory, notably with the internationally recognized Fundação Iberê Camargo.

The brand's touchpoints included urban furniture installed along the route from the city center to the stadium, where the 2014 World Cup matches took place, and international promotion materials (Multicity kit). Even after the World Cup, this furniture remained in place, now associated with another brand, Caminho do Gol. An identity for the Multicity brand was crafted through a promotional kit comprising a box, two postcards, and a booklet. In this kit, one of the symbols of Gaucho culture, the Estátua do Laçador, was not initially activated. However, during the campaign, the Laçador illustration was incorporated into the advertising pieces on Porto Alegre's urban furniture.

As the capital of Rio Grande do Sul, Porto Alegre boasts a rich history, dating back to its establishment in 1772, culminating in its status as a metropolis. The city serves as a cultural embodiment of the gaúcho heritage and, over time, has been a stage for power dynamics that have shaped its local, regional, and international identity. Throughout its history, Porto Alegre has been marked by both symbolic and tangible disputes, thereby influencing its present reputation and identity. While the brand narratives underscore the plurality of identities that have contributed to the city's foundation, the visual identity of "Multicity" has predominantly focused on generic tourist and cultural elements, lacking a connection with the local ethnicities. Despite the brand's attempt to highlight the city's ethnic diversity through the adoption of multiculturalism, it has not succeeded in creating a distinct identity separate from the dominant gaúcho culture. The revered symbol of the gaúchos, the Laçador Statue, was later incorporated into the brand campaign, albeit in a forced manner.

The strategic articulation of the city and the "Multicity" brand unveiled various tactics and maneuvers, including development strategies that shaped the social and cultural space of Porto Alegre. One of these strategies aimed to positively redefine the figure of the "gaúcho," linking it to the Farroupilha Revolution. This historical 10-year war solidified Gaucho culture, which has been hegemonic ever since. In the symbolic struggle to create a brand representing a multicultural identity, "Multicity" lost momentum and had to forcibly incorporate a symbol representing the "gaúcho," the Laçador Statue. These symbolic strategies highlight the power play and worldviews of social actors in the production of Porto Alegre, compelling it to engage with diverse social groups and the identity of the state.

Another contemporary strategy was the city's participation in an urban brand ranking in 2013, where Porto Alegre ranked seventh, with a value of BRL 20.8 billion, representing 48% of the Gross Domestic Product (GDP). This ranking contributed to "Multicity" gaining prominence during the 2014 World Cup, expanding its reach from local to global. The city's history revealed interests, uses, and appropriations of the territory, marked by wars,

political pacts, and symbolic disputes. The worldviews of social actors evolved over time, reflecting interests in the production, use, and appropriation of the territory, with the strategy of using brands as a representation of this process (Figure 3).

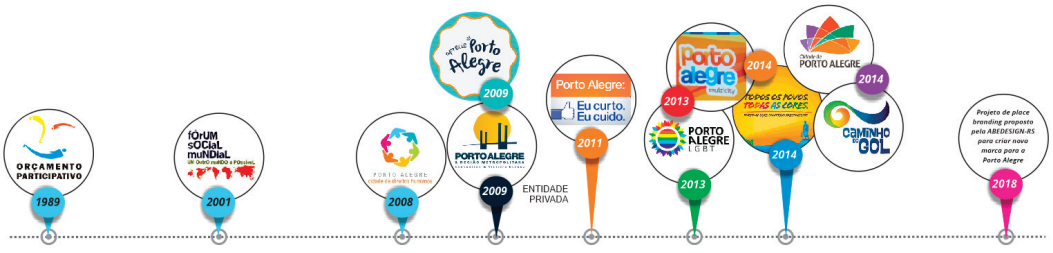


Figure 3. Territorial brands of Porto Alegre from 1989 to 2018. Source: Almeida [9].

Thus, a participatory, social, citizen-focused Porto Alegre emerged, intended to be appreciated, celebrated, and preserved, embracing LGBT diversity, multiculturalism, and representing "all peoples and all colors". Each of these facets of "Porto Alegre" refers to specific sets of forces, both internal and external, intertwining with other territorial dynamics on various scales and dimensions. The cultural focus of "Multicity" incorporated graphic elements from previous brands into its logo, as well as distinctive physical and symbolic features of the city. For example, the sunset of Porto Alegre and some of its tourist attractions stand out.

These are realities that delineate two distinct forms of territoriality: the territoriality of the brand and the territoriality of social actors. The territoriality of social actors is intrinsically linked to the uses and appropriations of the territory, involving the consumption of this space through the experiences promised by a brand, aiming to experience a multicultural city. The adjective "multicultural" gives the city a reputation that dissociates it from the hegemonic identity of the State, indirectly alluding to the city's previous brands. This approach is based on a set of beliefs, traditions, and infrastructures, such as the Centers of Gaúcho Traditions (CTGs) and monuments, centered on Gaúcho culture, to create an image of a strong and courageous people that exalts the qualities of the state and, consequently, of the city.

The territorialities of the brand encompass the power of that brand in multiple dimensions. Thus, the locations marked in "Multicity" refer to the historical and cultural context of the city, represented partially and graphically in the verbal-visual logo of the brand. More than a mere visual expression, "Multicity" is a discursive brand that proposed an alternative identity for the city, distinct from the identity of the State. In this symbolic struggle, "Multicity" lost strength, being discontinued in 2016 by the same government that created it, revealing a lack of understanding of the complexity of managing a territorial brand, specifically in the realm of place branding.

The application of the TBRD matrix in Porto Alegre revealed overlapping layers of power relations inherent in the Multicity brand. By delving into the theoretical framework of territorial brands and their relationship with the represented territory, the analysis of Porto Alegre Multicity using this methodological matrix enabled an integrated approach, linking macro and micro quadrants. This allowed analyses at different levels, contributing to a more comprehensive and continuous understanding of the process at hand.

5. Results and Discussion

The adjectives associated with city names, in the context of territorial brands in regional development, often lead to simplifications of the territory due to the dynamics of brand formats. When the brand of the city of Porto Alegre self-identifies as multicultural, it is not necessarily referring to the specific concept of multiculturalism as defined by Hall [3]. According to Hall [3], multiculturalism is an approach to observe and interpret the social

and cultural processes of a specific territory. In the case of Multicity, the term multicultural was used to address the diverse ethnicities that contributed to the formation of the city, although it does not directly represent the ethnicities present in contemporary times. Thus, by applying the TBRD matrix to the Porto Alegre Multicity brand (Figure 1), various layers of power relations and articulation strategies that influenced local urban transformations became evident (Figure 4).

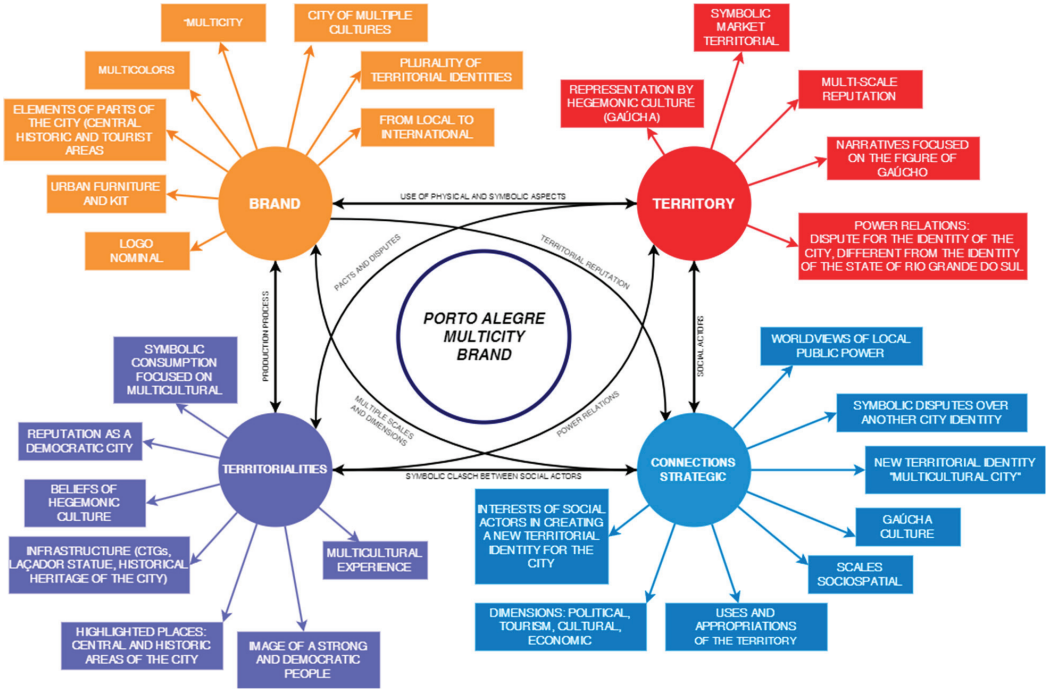


Figure 4. Methodological matrix TBRD applied to the Porto Alegre brand. Source: Author (2024).

Initially, during the analysis of Multicity, it was believed that the economic relationship (the most evident layer) drove the brand, as its launch coincided with the 2014 FIFA World Cup held in Porto Alegre. However, as we delved into the productive process of Multicity, another layer revealed itself: the cultural layer, related to the diverse ethnicities that contributed to the city's formation. The local government, the main actor in creating the brand in 2012, questioned the dominance of the hegemonic culture (Gaucha) over other cultures present in Porto Alegre, such as Arabs, Italians, Germans, Spaniards, and Afro-descendants. Thus, the brand, driven by a global sporting event, sought to highlight the cultural diversity of this territory, using the adjective multicultural adapted to the format of a brand.

The advancement in the study through the methodological matrix revealed an additional layer of power relations that went unnoticed in the Multicity brand: politics. This brand provided the local government with the opportunity to discuss why the territorial identity of Porto Alegre remained linked to the same territorial identity as the state of Rio Grande do Sul. Upon discovering the political layer of the brand, the strategic alignment of forces internal and external to the Porto Alegre territory became evident, resulting in a political clash between the capital and the state. The aim of this clash was to preserve the hegemonic territorial identity of the state, dissociating it from the territorial identity of the capital (Porto Alegre) and giving it a more "plural," more multicultural identity (Multicity).

The proposed methodological matrix highlighted a complex set of relationships between brands and territories, revealing several overlapping layers of power that conceal other dimensions. The four macro quadrants of the TBRD matrix revealed a political-cultural clash, with an emphasis on tourism associated with economic development. In addition to the economic and touristic layers, more visible in the Multicity brand and strategies, a cultural layer emerged that underpinned the advertising campaign. However, a hidden layer was identified, the political layer, which triggered a political conflict over the distinction of Porto Alegre's territorial identity in relation to the state's identity. This conflict was driven by the public authorities, which since 2009 sought to create a more democratic identity for the city, overcoming the dominance of a single culture, the hegemonic one. Only in 2012, with the proposal for Porto Alegre to be a host city for the 2014 World Cup, did this intention gain strength. However, the attempt to detach the city's identity from the state's identity was unsuccessful, requiring the forced inclusion of one of the symbols of Gaucho culture, the statue of the Laçador.

In 2016, the government that originated Multicity deactivated it, an unusual action. However, the creation, maintenance, and deactivation of territorial brands over time are part of the process involving the power relations of these brands. Furthermore, the subsequent government of Porto Alegre did not fully adopt Multicity, replacing its name with Caminho do Gol (another brand created at the time that symbolically competed with Multicity). However, the graphic elements and urban furniture of Multicity remained in the "new" brand. This indicates that the idea of a multicultural city was introduced but has not yet managed to symbolically compete with the hegemonic identity of the state, reflected in its capital, Porto Alegre. Thus, the TBRD matrix reveals, in addition to its quadrants, four underlying connections: protagonism, legitimacy, power, and dynamics (Figure 5).



Figure 5. Subjacent connections to the TBRD matrix. Source: developed by the Author (2024).

These identified connections refer to each of the axes of the TBRD matrix and its micro variables. It is not a new matrix but another way of understanding Almeida's theory [18] about "territorial brands as a cultural artifact of regional development". With this perception, it is understood that territorial brands are more than simple logos (graphic representations of brands) applied to territories; they are cunning strategies of social actors to legitimize their ideological discourses. In the process of discursive legitimation facilitated by the territorial brand, the territory gains protagonism, often strategically concealing social actors as subjects of action. This occurs when, for example, it is stated that "the city" aspires to be "multicultural" or any other interest, even though the city cannot be the subject of action as it is not a human being. With this artifice, social actors create dynamics that generate convenient interconnections to realize their interests in the territory. In doing so,

power relations intertwine with social practices and often go unnoticed, although they are present.

The TBRD matrix plays a crucial role in facilitating the identification of power relations associated with the creation, maintenance, and even deactivation of territorial brands. It is essential to understand that when deactivating a territorial brand, a new one is often activated in its place, with new interests and frequently involving a new set of social actors. Therefore, even though Multicity was deactivated in 2016 by the same government that created it, this is not a unique case but rather a recurring phenomenon in various other territorial brands, including those with long-term existence.

This study, while focusing on investigating the case of the Multicity brand, extended its analyses to other brands through the application of the TBRD matrix during the construction and applicability phase of this matrix. This approach allows for the replication of the study in relation to other brands and contexts. However, the choice to dedicate the study to a specific case was motivated by the complexity of interdisciplinary discussions involved in the productive process of a territorial brand. The pioneering work of Almeida [9], addressing territorial brands from the theories of regional development, gave rise to a new theory in this field, culminating in the creation of the TBRD matrix.

6. Conclusions

The TBRD matrix, conceived as an analytical protocol, proved to be an effective tool for exploring the complex relationships between territorial brands and the territories they represent. This study confirmed the premise that events in the territory exert a significant influence on shaping territorial brands over time and space, during their processes of development and territorial management. The analysis extended to various scales and dimensions, encompassing realities beyond the specific case studied.

The proposed objective was fully met, as the TBRD matrix provided a comprehensive understanding of the power relations present in the territory, arranged in overlapping layers, some consolidated over time and others in the process of construction. These relations were identified as symbolically incorporated elements in the territorial brand.

6.1. Main Findings

The results highlighted the overlap of layers of power relations in the territory, facilitated by territorial brands, which anchor themselves in specific parts of a city's (or another scale's) territory, without covering all territories of the city, state, region, or country. The analysis of the evolution of territorial brands in a specific territory revealed overlapping layers that, when confronted with territorial reality, exposed the discourses of various sets of social actors, which transform over time.

This research addressed the relationship between brands and territories in the context of regional development [9], proposing the application of a specific analytical matrix (TBRD). When applied to an individual reality or a set of realities (city, region, and country), the matrix highlights the contradictory processes between the local and the global that occur in the territory, produced by sets of social actors who adopt different approaches in the production of lived space.

Considering competitiveness and reputation in territories, territorial brands can be understood as mechanisms for legitimizing symbolic discourses, creating a planned and intentional (urban and territorial) imaginary. This may not always correspond to reality but reflects the worldview of social actors in the competition and appropriation of the territory. Thus, the territory represented by territorial brands assumes a certain protagonism as the subject of an action.

6.2. Contributions

The contributions of this research are significant in deepening the understanding of the relationships between brand and territory(ies), developing the concept of territorial brand in the context of regional development, and expanding the theoretical framework

surrounding brand-territory-regional development. For the city of Porto Alegre, public administrators, and territorial brand strategists, the TBRD matrix represents an opportunity for insights into the set of relationships present in the territory, extending to regions and the country.

It is important to emphasize that the study is not limited to the specific reality of Porto Alegre but provides theoretical insights into the symbolic meanings of structures and power relations generated by territorial brands in the context of regional development, involving territorial management. Thus, the research can be generalized to other empirical realities, investigating the power relations of social actors in a geographical-territorial delimitation that uses the strategy of a territorial brand. The TBRD matrix exposes the dynamics of strategies adopted by social actors in the production, use, and appropriation of the territory, regardless of its geographical scale. The case analysis of Porto Alegre allows for examining the layers of overlapping power relations in that territory, aligning with Almeida's [9] perspective that the territorial brand is a cultural artifact and a result of the dynamics of the territory in productive, strategic, and creative processes.

This research can be considered a complement to Almeida's [9] studies, confirming the existence of power relations through territorial brands. However, it differs by describing and analyzing different levels of overlapping power layers, strategically articulated by social actors, using territorial brands as mechanisms to legitimize the discourses of a particular set of social actors. This approach acknowledges the presence of power relations in territorial brands but highlights their arrangement in overlapping layers, some visible and others intentionally hidden. The study also contributes to the understanding of interactions between people (social actors), place (territory), and the environment, using appropriate methods, introducing the novelty of a matrix that explores the nuances of power relations through territorial brands.

6.3. Implications

6.3.1. Theoretical

The study contributes to the expansion of understanding about territorial brands, highlighting them not only as graphic representations but as cultural artifacts that reflect complex dynamics of power, the legitimation of discourses, and the production of territorial meanings. The application of the TBRD matrix allows for a deeper analysis of the relationships between brand and territory in the context of regional development, providing a theoretical foundation to understand how territorial brands are linked to the productive, strategic, and creative processes of the territory.

6.3.2. Social

By highlighting the underlying layers of power in territorial brands, the study draws attention to the social construction of territorial identities, showing how different social actors seek to influence and shape these identities according to their interests. The study contributes to a deeper understanding of the symbolic struggle that takes place in the creation and management of territorial brands. This can raise awareness in society regarding the symbolic implications of brands and their connections to local power and politics.

6.3.3. Practical

Public officials and territorial brand strategists can benefit from the TBRD matrix as a practical tool to understand the dynamics and power relations involved in the creation and management of territorial brands. This can inform strategies that are more aligned with territorial and social realities. The analysis of power layers can empower decision-makers to consider more deeply the social and cultural implications when developing, maintaining, or deactivating territorial brands. This can result in more informed decisions that align with community interests. The study can stimulate public discourse on the construction of territorial identities, leading to more conscious and active participation by society in defining the image and identity of their territories.

6.4. Limitations and Suggestions for Future Research

The limitations of this research are related to the number of territories investigated, indicating the need for future research to expand the possibilities of the proposed matrix. From this study, new lines of investigation may arise, such as the analysis of territorial interventions through territorial brands from the perspective of territorial-regional development. As a suggestion for future research, the application of the TBRD matrix in multiple cases is proposed to identify similarities and differences between the power layers present in territorial brands. Furthermore, the matrix can be used as a practical tool for managers, providing a more comprehensive and effective assessment of the power dynamics involved in these initiatives.

6.5. Final Considerations

In conclusion, it is reaffirmed that the TBRD matrix proves to be appropriate for highlighting and understanding the overlap of layers of power relations in the territory, as well as the local and global contradictions in the space shaped and represented by territorial brands, extending to socioterritorial interventions. Furthermore, the understanding of the relationship between brand and territory is broadened, providing insights for a more effective territorial management of these brands. The research not only reinforces the importance of brands as indicators of power but also highlights their potential to shape and disseminate ideologies among the various social actors present in the territory.

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References

1. Williams, R. C*ulture and Materialism*; Editora Unesp: São Paulo, Brazil, 2011.
2. Du Gay, P.; Hall, S.; Janes, L.; Madsen, A.K.; Mackay, H.; Negus, K. *Doing Cultural Studies: The Story of the Sony Walkman*; Sage: London, UK, 1997.
3. Hall, S. Ideology and Communication Theory. *Matrizes* **2016**, *10*, 33–46. [CrossRef]
4. Santos, M. *The Nature of Space: Technique and Time, Reason and Emotion*; Hucitec: São Paulo, Brazil, 1996.
5. Pecqueur, B. Territorial development: A new approach to development processes for the economies of the South. *Raízes* **2005**, *24*, 10–22. [CrossRef]
6. Raffestin, C. *For a Geography of Power*; Ática: São Paulo, Brazil, 1993.
7. Vela, J.S.E.; Portet Ginesta, X.; Algado, S.S. From the trademark to the territorial brand: The cases of the doc Priorat and do Montsant. *Hist. Comun. Soc.* **2014**, *19*, 67–78.
8. Kavaratzis, M. Place branding scholars and practitioners: Strangers in the night? *J. Place Manag. Dev.* **2015**, *8*, 266–270. [CrossRef]
9. Almeida, G.G.F. Marca Territorial Como Produto Cultural no Âmbito Do Desenvolvimento Regional. Doctoral Thesis, University of Santa Cruz do Sul, Santa Cruz do Sul, Brazil, 2018. Available online: http://hdl.handle.net/11624/798 (accessed on 15 January 2024).
10. Garreton, M.; Castro, A.; Valenzuela, L. Imaginaries of Urban Development: Glimpses of Local Cooperation in a Neoliberal and Competitive Metropolis. *Revista* **2017**, *180*, 94–107.
11. Lefebvre, H. *The Right to the City*; Moraes: São Paulo, Brazil, 1991.
12. Geertz, C. *The Interpretation of Cultures*, 1st ed.; LTC: Rio de Janeiro, Brazil, 2008.
13. Cresswell, T. *Place: A Short Introduction*; Wiley: Malden, MA, USA, 2004.
14. Blij, H.J. *The Power of Place: Geography, Destiny, and Globalization's Rough Landscape*; Oxford University Press: Oxford, UK, 2009.
15. Cunha, P.J.A.M. Conflict in the appropriation of cultural heritage: The conservation of the Armando de Holanda park. *Bitácora Urbano Territ.* **2021**, *31*, 215–227.
16. Almeida, G.G.F. A Identidade Territorial Gaúcha No Branding das Marcas Regionais: Caso da Marca da Cerveja Polar. Master's Thesis, University of Santa Cruz do Sul, Santa Cruz do Sul, Brazil, 2015. Available online: http://hdl.handle.net/11624/2246 (accessed on 1 January 2024).

17. Lucarelli, A. Place branding as urban policy: The (im)political place branding. *Cities* **2018**, *80*, 12–21. [CrossRef]
18. Anholt, S. *Places: Identity, Image, and Reputation*; Palgrave Macmilan: London, UK, 2010.
19. Castells, M. *The Power of Identity*; Paz e Terra: São Paulo, Brazil, 2006.
20. Canclini, N.G. *Consumers and Citizens: Multicultural Conflicts of Globalization*; Universidade Federal do Rio de Janeiro: Rio de Janeiro, Brazil, 2010.
21. Haesbaert, R. The Geographical Dimension of Culture: Territory and Identity as Categories of Socio-Political Practice. In Proceedings of the Seminar Cultural Studies and Interdisciplinary Interlocutions: Relations between Culture and Regional Development, Santa Cruz do Sul, Brazil, 2 July 2016.
22. Flores, M. A Identidade Cultural do Território como Base de Estratégias de Desenvolvimento: Uma Visão do Estado da Arte. 2006. Available online: https://indicadores.fecam.org.br/uploads/28/arquivos/4069_FLORES_M_Identidade_Territorial_como_Base_as_Estrategias_Desenvolvimento.pdf (accessed on 15 January 2024).
23. Sabourin, E. Territorial development and territorial approach: Concepts, strategies, and actors. In *Planning and Development of Rural Territories: Concepts, Controversies, Experiences*; Sabourin, E., Teixeira, O.A., Eds.; Embrapa Informação Tecnológica: Brasília, Brazil, 2002; pp. 21–37.
24. Gertner, D. Unfolding and configuring two decades of research and publications on place marketing and place branding. *Place Brand. Public Dipl.* **2011**, *7*, 91–106. [CrossRef]
25. Feijó-de-Almeida, G.-G. Territorial Brand strategies in the representation and reputation of territories in the field of Regional Development. *Rev. EURE—Rev. Estud. Urbano Reg.* **2023**, *49*, 1–24. [CrossRef]
26. Aaker, D. *Creating and Running Successful Brands*; Futura: São Paulo, Brazil, 1996.
27. Holt, D.B. *How Brands Become Icons: The Principles of Cultural Branding*; Cultrix: São Paulo, Brazil, 2005.
28. Semprini, A. *The Postmodern Brand: Power and Fragility of the Brand in Contemporary Society*; Estação das Letras e Cores: São Paulo, Brazil, 2010.
29. Strunck, G.L.T.L. *How to Create Visual Identities for Successful Brands*; Rio Books: Rio de Janeiro, Brazil, 2001.
30. Tajada, L.A.S. *Integration of the Company's Identity and Image*; ESIC: Madrid, Spain, 1994.
31. Lindstron, M. *Brandsense: Sensory Secrets Behind the Things We Buy*; Bookman: Porto Alegre, Brazil, 2012.
32. Pinho, J.B. *The Power of Brands*; Grupo Editorial Summus: São Paulo, Brazil, 1996.
33. Grehan, K. *Gramsci, Cultura e Antropologia*; Pluto Press: London, UK, 2002.
34. Luna, E.S. From nobles and avatars: The subway as a cultural space in Mexico City. *Bitácora Urbano Territ.* **2021**, *31*, 143–156.
35. Montero Graniela, A. Creative Economies in Historic Centres: Old Havana. *Bitácora Urbano Territ.* **2021**, *31*, 189–202. [CrossRef]
36. Mariutti, F.G. Theoretical foundations on place marketing, place brand management, and place brand value. *Comun. Merc.* **2019**, *6*, 163–184.
37. Albagli, S. Territory and territoriality. In *Territories on the Move: Culture and Identity as a Strategy for Competitive Insertion*; Lages, V., Braga, C., Moreli, G., Eds.; Relume Dumará: Rio de Janeiro, Brazil, 2004; pp. 24–65.
38. Yin, R.K. *Case Study Research Design and Method*; Sage Publications: New York, NY, USA, 2015.

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Modeling the Interactive Patterns of International Migration Network through a Reverse Gravity Approach

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Abstract: The international migration network, comprising the movements of people between countries, is one of the most important global systems of interaction, which can reflect the complex international relations of economics, cultures, and politics and has huge impacts on global sustainability. However, the conventional gravity model cannot model its complicated interactions accurately. In this article, we propose a novel reverse gravity model using genetic algorithm to reconstruct the complicated interaction patterns with high accuracy. To verify the feasibility of our method, it was applied to a series of international migration networks. We found that the derived node attractions were highly correlated with socioeconomic factors and network metrics, and the calculated node positions outperformed the geometric centers from the perspective of human migration that related to economy and demography. Our approach could be a preferred choice to investigate the spatial–temporal interactive patterns in geographical space, facilitating comprehension of the mechanisms underlying their generation and evolution.

Keywords: reverse gravity model; international migration; human geography; genetic algorithm; spatial interaction networks

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1. Introduction

International migration is a significant matter of interest, not only in the study of demography but also in the domains of human geography, human mobility, and spatial analysis [1,2]. It has a complex impact on global sustainability [3,4]. Constructing international migration networks is an often-used approach [5,6]; the network structure is a good representation of migration flows, and the complex network theory offers a rich diversity of methodologies to examine the characteristics of population interactions. By analyzing the small-world and scale-free properties of the network, as well as the centrality of nodes and community division, researchers can evaluate the structural features of international migration [7–10].

The international migration networks, apart from the topological properties, are also distinguished by their spatial interaction features and are typical instances of spatial interaction networks. On the one hand, by taking spatial factors into account, the community structure and node centrality of the network are different from general complex networks [11,12]. On the other hand, the simulating and modeling of spatial interactions is also a research focus which could help to yield a better understanding of the spatial–temporal patterns within [13,14].

There are many models that migration networks could be fitted into [15], among which the most famous are the gravity model [16], radiation model [17], and intervening opportunity model [18]. The gravity model draws inspiration from Newton's law of gravitation, in that the strength of the interaction is in proportion to the mass of both sides and the inverse of the squared distance between them; it was originally introduced to study the correlations among population, distance, and intercity migrations [19]. Now this

law has been empirically found to exist in various systems, including international trade networks, communication networks, social tagging networks, and others [20–22]. From the perspective of modeling, gravity is distinguished by its easily representable nature of interaction [23]. There is a rich body of academic literature in this field, focusing on how to implement this framework and get a better estimation [24]. The radiation model and intervening opportunity model, drawing on the radiation and absorption process in solid state physics, are also widely used and have proven to be effective in predicting human mobility [25,26]. However, these two models are mainly used in urban and interurban migration [27], while the gravity model is a more preferable choice on the international scale. Despite their effectiveness, these three models still face challenges in finding the appropriate instrumental variables [16]: a poor choice in instrumental variables may lead to bad-fitting results. Another research gap for them is the calculation of distance [28]: the suitability of distance representation between two irregular geographical units also affects the modeling effect. Although the Euclidean distance between the centroids of geographical units is the usual practice, the justification of centroids remains uncertain.

To tackle the first shortcoming, the reverse gravity model, or a reverse-fitting method of the gravity model, is applied [29]. This approach attempts to reconstruct the theoretical attractions of nodes from known spatial interactions and distances; it has also developed many different algorithms [30]. This method is an easily conducted data-driven approach aiming to obtain the best fit and is useful for interaction networks where the relations are complex and factors are hard to identify. However, the proper representation of distance remains a difficult task.

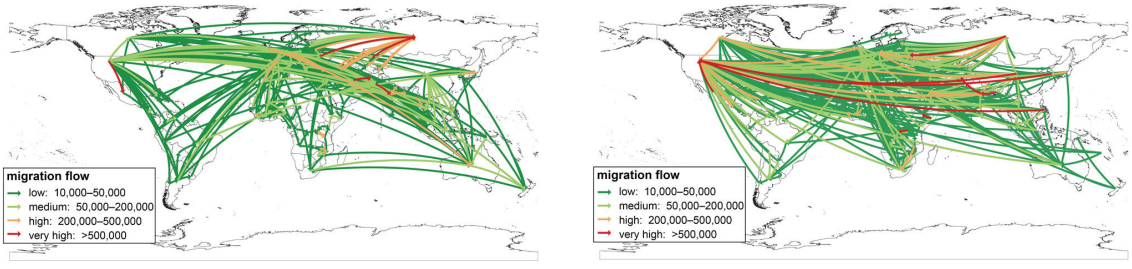
In this article, we proposed a modified reverse gravity model based on genetic algorithm, where not only bidirectional attractions but also a practical position for each node were identified, from which the distances could be calculated. This method was applied to a series of international migration networks: the results revealed the latent spatial–temporal interactive patterns and were compared to other socioeconomic observations. In Section 2, the dataset and our proposed method are elucidated. In Section 3, the results on network properties and reverse gravity fitting are presented, including patterns of node attractions and positions. Sections 4 and 5 present the discussion and conclusions of our study.

2. Materials and Methods

2.1. Data

The international migration networks we used in this article were constructed from a set of five-year estimations of international migration flows, ranging from mid-year 1990 to mid-year 2020; the bilateral flow data were estimated based on migration stock data using a closed demographic accounting method with a pseudo-Bayesian approach [31]. This representative dataset has been widely used in recent studies, where the international migration is defined based on changes in place of residence [32,33]. For example, if the intensity of the flow from Country A to Country B in one period is 100, then there are 100 people who were first living in Country A but at the end were living in Country B. To match up with other data, we chose 194 countries. We constructed six directed weighted networks where nodes represented countries and edges indicated the migration flow from the source country to the target country, and the weights of edges were equal to the amount of people. These networks represented international migration in six periods: 1990–1995, 1995–2000, 2000–2005, 2005–2010, 2010–2015, and 2015–2020. All networks were strongly connected. The visualization and basic statistics of these networks are shown in Figure 1 and Table 1.

The administrative areas of countries were primarily obtained from the GADM project (https://gadm.org/data.html, accessed on 10 March 2024), while the administrative area of China was acquired from the Resource and Environment Science and Data Center (https://doi.org/10.12078/2023010103, accessed on 10 March 2024). These data were used to calculate the geometric center.



(**a**) (**b**)

Figure 1. Example of the international migration network, with (**a**,**b**) displayed flows from west to east and east to west presented separately in the same network. The geometric center of the country is used as the position and the arrow indicates the direction of the edge. The color of the arrow represents the weight. Edges with very low weight (<10,000) are discarded for better visualization.

Table 1. Basic statistics of international migration networks.

Period	Number of Nodes	Number of Edges	Sum of Weights
1990–1995	194	24,937	66,160,782
1995–2000	194	25,372	66,025,147
2000–2005	194	25,729	71,575,382
2005–2010	194	26,088	83,411,284
2010–2015	194	26,371	90,879,826
2015–2020	194	26,598	93,155,493

The gross domestic product (GDP) and population data of all countries were downloaded from the World Bank. The inward and outward flow of foreign direct investment (FDI) were downloaded from the United Nations Conference on Trade and Development. These data could reflect the socioeconomic status of a country and could be used as the determining factor in international migration [34,35].

2.2. Complex Network Theory

2.2.1. Scale-Free and Small-World Properties

For complex networks, there are two main properties of concern: scale-free and small-world. The scale-free network is the one with a power-law degree distribution [36]:

$$Pr(X) = kX^{-\alpha}, \tag{1}$$

where X is the degree (or weighted degree), α is the scaling parameter, and k is a normalization constant. This distribution means that a large fraction of the links (or weights) fall to a small fraction of nodes, resulting in heterogeneity of the network [37]. A fitting technique designed for empirical data is always used [38].

The small-world effect reflects the fact that the distances between pairs of nodes are short. Mathematically speaking, if a network has a greater average clustering coefficient as well as an equal or smaller average shortest path length compared to random networks of the same size, it is a small-world network. The small-world-ness can be quantitatively measured [39]. In a directed weighted network, the clustering coefficient is [40]

$$cc_i = \frac{\sum_j \sum_h \left(w_{ij}^{1/3} + w_{ji}^{1/3}\right)\left(w_{ih}^{1/3} + w_{hi}^{1/3}\right)\left(w_{jh}^{1/3} + w_{hj}^{1/3}\right)}{2\left[s_i^{tot}\left(s_i^{tot} - 1\right) - 2s_i^{\leftrightarrow}\right]}, \tag{2}$$

where w_{ij} denotes the weights of the edge from i to j, s_i^{tot} is the sum of in-strength and out-strength of node i, and $s_i^{\leftrightarrow}$ is the reciprocal strength of i, which is calculated as

$s_i^{\leftrightarrow} = \sum_{j \neq i} w_{ij} w_{ji}$. This equation captures the fraction of all possible geometric means of subgraph edge weights.

2.2.2. Betweenness Centrality

There are many centrality measures to evaluate the importance of a node [41]; of them, the betweenness centrality has been proven to have a vital role in community detection [42], finding influential nodes [43], and other tasks. Betweenness centrality is calculated as the sum of the fractions of shortest paths that go through a given node [44]:

$$bc_i = \sum_{s,t} \frac{\sigma_{s,t|i}}{\sigma_{s,t}}, \tag{3}$$

where $\sigma_{s,t}$ is the number of shortest paths from node s to t, and $\sigma_{s,t|i}$ is the number of shortest paths from s to t that go through i.

2.2.3. PageRank

PageRank was initially designed to rank web pages based on links between them; a web page is more important if it can be redirected from other important web pages [45]. This idea can be represented by the iterative formula below:

$$pr_i = \delta * \sum_{j \in nei_i} \frac{pr_j}{d_j} + \frac{1-\delta}{N}, \tag{4}$$

where nei_i is the set of neighbors of node i, d_j is the degree of node j, N is the number of nodes, and δ is the dangling factor. For weighted networks, the scaling factor $\frac{1}{d_j}$ should be $\frac{w_{ji}}{\sum_h w_{jh}}$. The iterative process can be seen as a Markov process, and the PageRank vector is then defined as the stationary density of a discrete-time random walk on the network, leading to an algebraic approach to the problem [46].

2.3. Reverse Gravity Model Based on Genetic Algorithm

2.3.1. The Gravity Model

There exist numerous variations of the gravity model; in this article, a basic form was used. The gravity model considers differences between origins and destinations, and the distance decay parameter β is not fixed [19,23]. The model can be written as

$$G_{ij} = k P_i^{out} P_j^{in} d_{ij}^{-\beta}, \tag{5}$$

where G_{ij} is the geographical flow, P_i^{out} and P_j^{in} are the theoretical importances for the origin giving out flows and the destination taking in flows, and d_{ij} is the distance between them. The two factors are referred to as node attractions and are always denoted as $P_i^{\alpha_{out}}$ and $P_i^{\alpha_{in}}$, indicating the same variable with different exponents.

When applying the gravity model to analyze international phenomena such as migration and trade, where i and j stand for countries, the variables typically encompass population size, GDP, or GDP-per-capita [47,48]. Additionally, distances are always calculated between geometric centers or capital cities [28,49]. Using the logarithm form, Equation (5) then becomes linear:

$$ln(G_{ij}) = ln(k) + ln(P_i^{out}) + ln\left(P_j^{in}\right) - \beta\, ln(d_{ij}) = ln(k) + \alpha_{out}\, ln(P_i) + \alpha_{in}\, ln(P_j) - \beta ln(d_{ij}), \tag{6}$$

then ordinary least squares (OLS) and other linear regression methods can be used to solve the parameters α_{out}, α_{in}, and β.

In many situations, the positive impact of GDP, population, or other variables on the number of flows is likely to be found, but the model may not be well-fitted due to a complex causal relationship. An alternative approach is to incorporate other factors into the equation, such as the Global Innovation Index, the Environment Index, average life expectancy, and dummy variables indicating whether the two countries are contiguous and share a common official language [28,50].

2.3.2. The Reverse Gravity Model

The reverse gravity model refers to the same equation as mentioned above but applies it in reverse to derive node attractions from the observed G_{ij} and d_{ij}. This approach simplifies the task of identifying and combining multiple related factors into the calculation of a single factor. Methods like linear programming [51], algebraic calculation [29,52], and OLS regression based on dummy variables [53] have been considered. More recently, a particle swarm optimization (PSO) approach was proposed and was found to achieve a better reconstruction of node attractions [30].

In this article, we proposed a new reverse gravity model using genetic algorithms (GA). GA, like PSO, is a heuristic algorithm aiming to find the best solution through an iterative optimization process and has been widely applied in research and engineering [54]. This algorithm is inspired by the genetic process in nature [55]. There are some terms in this algorithm. A solution or individual is a set of values, known as genes, which can yield a certain fitness. The population is a group of individuals. This algorithm operates as the population evolves into new generations. During the process, individuals are mating and mutating, which means genes are exchanging and changing randomly, leading to different solutions and fitness, and the favorable ones will be kept. Finally, after enough generations of searching, it will find the best solution.

To reverse fit the gravity model is to search for the best logarithm of P_i^{out} and P_i^{in} for every node, as well as the parameter β. The goodness of fitness can be represented by the adjusted R^2 between actual and simulated flows. Moreover, we have introduced a technique to overcome the limitations of distance representation. By employing a similar genetic algorithm approach, the positions of nodes are found, and consequently, the distances can be calculated.

In summary, we proposed a reverse gravity approach with two stages of an alternate renewal process, where the two stages represent searching for node attractions and positions, respectively, and GA is used in each stage. The flow chart of our method is shown in Figure 2. (1) For a spatial interaction network of N geographic units, the first step is to calculate the pairwise distances of all nodes with the geometric center. (2) Next, we prepare a population with $2N + 1$ genes for each individual, where the genes represent bidirectional node attractions and the distance decay parameter β, and we run GA to obtain the best solution. (3) We prepare a population of identical individuals. Each has $2N$ genes with the values of node positions, and we run GA given the previous best node attractions and parameter β. (4) We run another GA to search for the best node attractions and parameter β, based on the previous best positions of nodes. (5) We repeat Steps 3 and 4 until the goodness of fitness converges, and the attractions and positions of nodes and the distance decay parameter are obtained. In this article, the geographic units are countries.

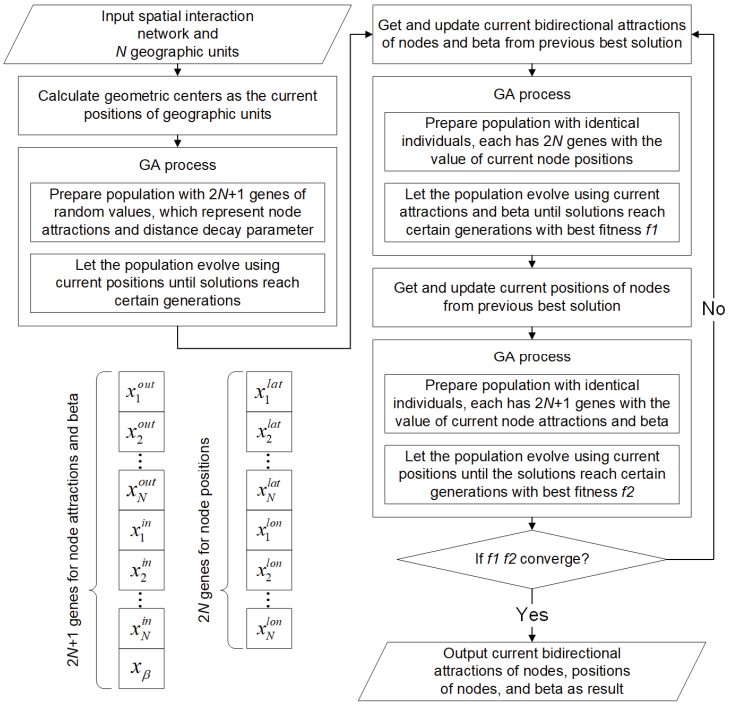


Figure 2. Flow chart of the reverse gravity approach with two stages of alternate renewal process.

3. Results

3.1. Structural Properties of the International Migration Networks

3.1.1. Scale-Free

We noticed that the weighted degrees of the United States, Russia, India, Germany, and the United Kingdom added up to 25.5%, 28.0%, 26.2%, 25.3%, 23.1%, and 24.8% of the total weights for six periods respectively; this may suggest a scale-free property. To investigate this, weighted degrees along with weighted in-degrees and out-degrees were fitted. In Figure 3, distributions of all periods are exhibited. We found that all distributions fitted well with the power law, which demonstrates obvious scale-free properties in international migration networks. The result indicates that a large amount of migration was related to only a small number of countries. The heterogeneity of weighted degree distribution declined from 1990 to 2010 as the scaling parameter decreased.

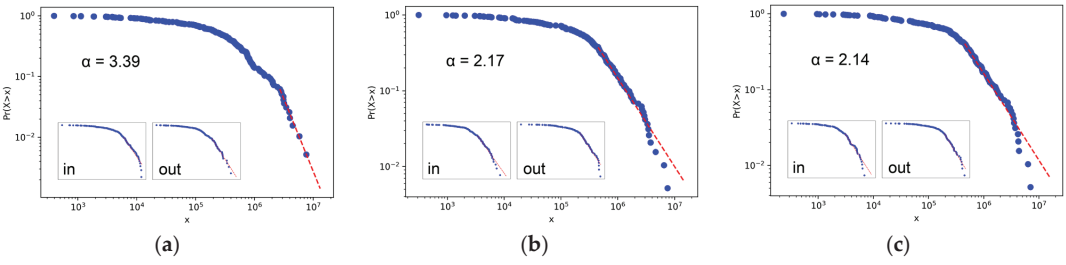
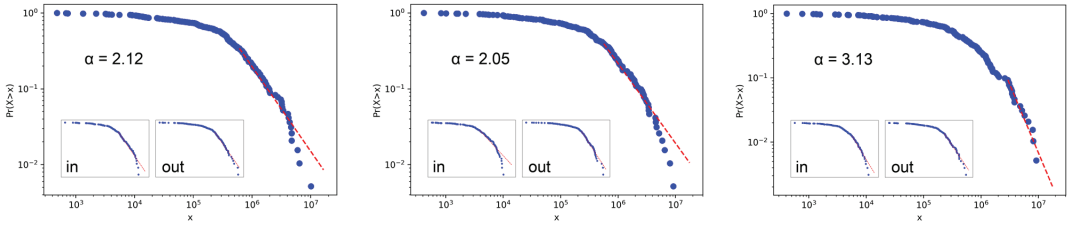


Figure 3. *Cont.*

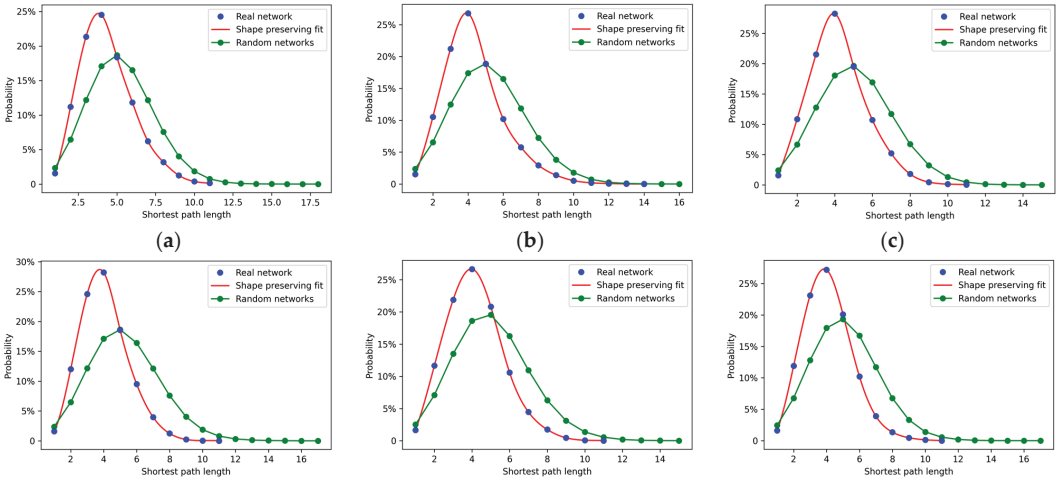


(**d**) (**e**) (**f**)

Figure 3. The weighted degree distribution (along with the in-degree and out-degree) of international migration networks can be well-fitted by a power-law distribution, indicating scale-free properties in these networks; (**a**–**f**) refer to 6 periods.

3.1.2. Small-World

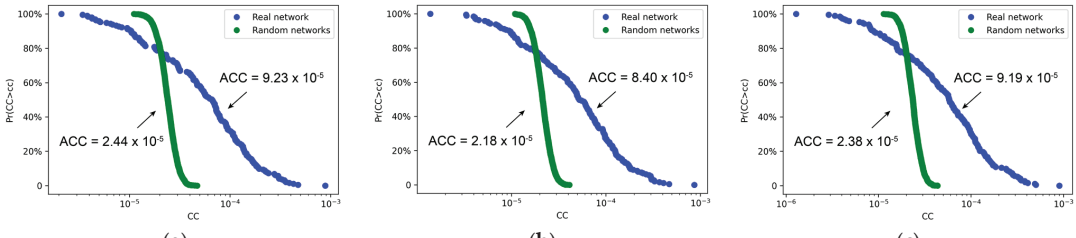
Migration networks should be compared to random networks of the same scale to investigate the small-world property. Here we generated 100 random networks for each period, with not only sums of edge weights but also distributions of edge weights kept the same as the real networks. Then, the distributions of shortest path lengths and clustering coefficients for both real networks and the averages of random networks were measured. Results are shown in Figures 4 and 5.



(**a**) (**b**) (**c**)

(**d**) (**e**) (**f**)

Figure 4. The shortest path length of real international migration networks (blue marker) and the averages of random networks (green marker) of the same scale; (**a**–**f**) refer to 6 periods.



(**a**) (**b**) (**c**)

Figure 5. *Cont.*

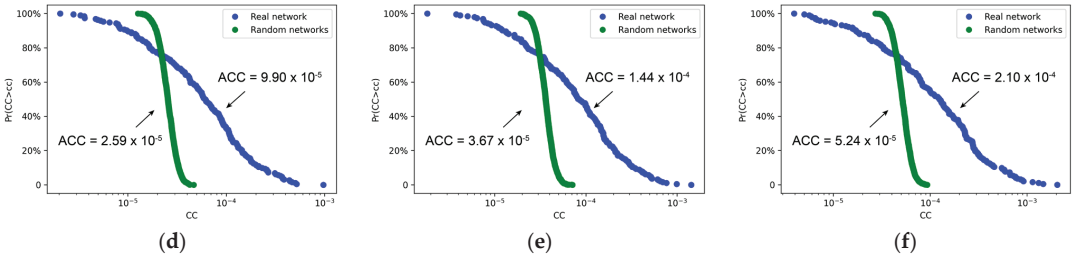


Figure 5. The weighted clustering coefficient of real international migration networks (blue marker) and the averages of random networks (green marker) of the same scale; (**a**–**f**) refer to 6 periods.

The shortest path lengths of real networks were slightly smaller than those of random networks, while the clustering coefficients were bigger. Using the quantitative measure, the small-world-ness values for each period were 4.58, 4.64, 4.71, 5.01, 4.78, and 5.01. This result showed that the international migration networks had a small-world effect. It should be noted that the reciprocal of edge weight was used for calculating the shortest path length. The existence of both scale-free and small-world properties in international migration networks suggested a complex interactive pattern and emphasized the importance of our subsequent research.

3.2. Interactive Patterns of the International Migration Networks

3.2.1. The General Results of Our Method

For six international migration networks, our method was used to find the node attractions and positions, as well as the distance decay parameter. For each searching stage in our method, the maximum number of iterations was set to 2000, and the population size was 50, in which 20 individuals were selected for mating, and 10% of genes would mutate. The goodness of fitness curves in Figure 6 demonstrate this procedure. We found that the optimal solutions were likely to be roughly identified in the first two stages and to converge in the subsequent stages. The final adjusted R^2 reached 0.67–0.69, which suggested that the node attractions and positions our method found could interpret a significant portion of the observed data.

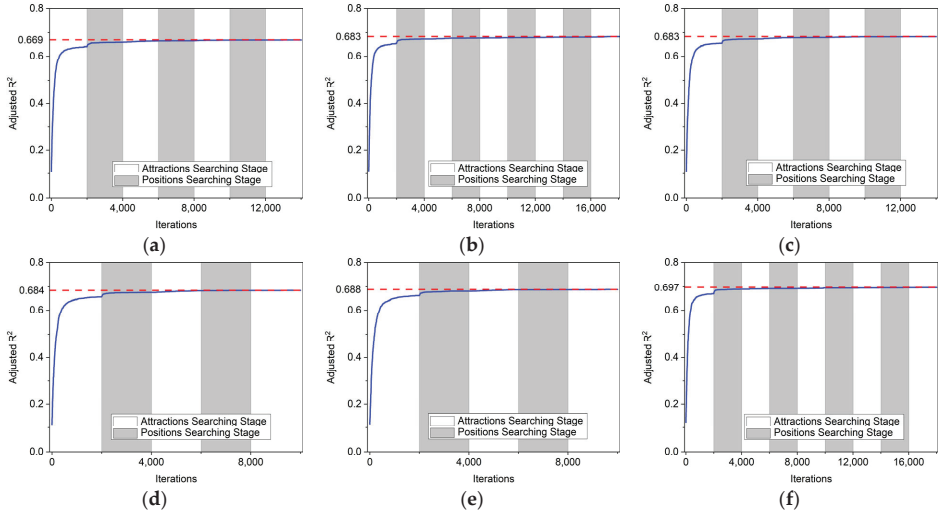


Figure 6. The goodness of fitness curves: different background colors represent different searching stages, the dashed red line denotes the convergence value, and (**a**–**f**) refer to 6 periods.

3.2.2. Node Attraction Patterns

The derived node attractions, which indicate the ability of pushing and pulling migration flows, are shown in Figure 7 (full results in Table S1). In general, P_{out} and P_{in} were correlated, which consisted in the assumption of using the same variable in the classic gravity model [19,56]. From the results, we could find some other patterns, which suggested different roles for different countries in spatial interactions. (1) Countries like the United States, Canada, Australia, and the United Kingdom ranked high in both attractions, indicating their activeness in international migration at all times. (2) Developing countries like China, India, and South Africa in most cases had a relatively stronger outward attraction. (3) Developed countries such as Germany and France had a relatively stronger inward attraction in the periods of 1995–2000, 2005–2010, and 2015–2020.

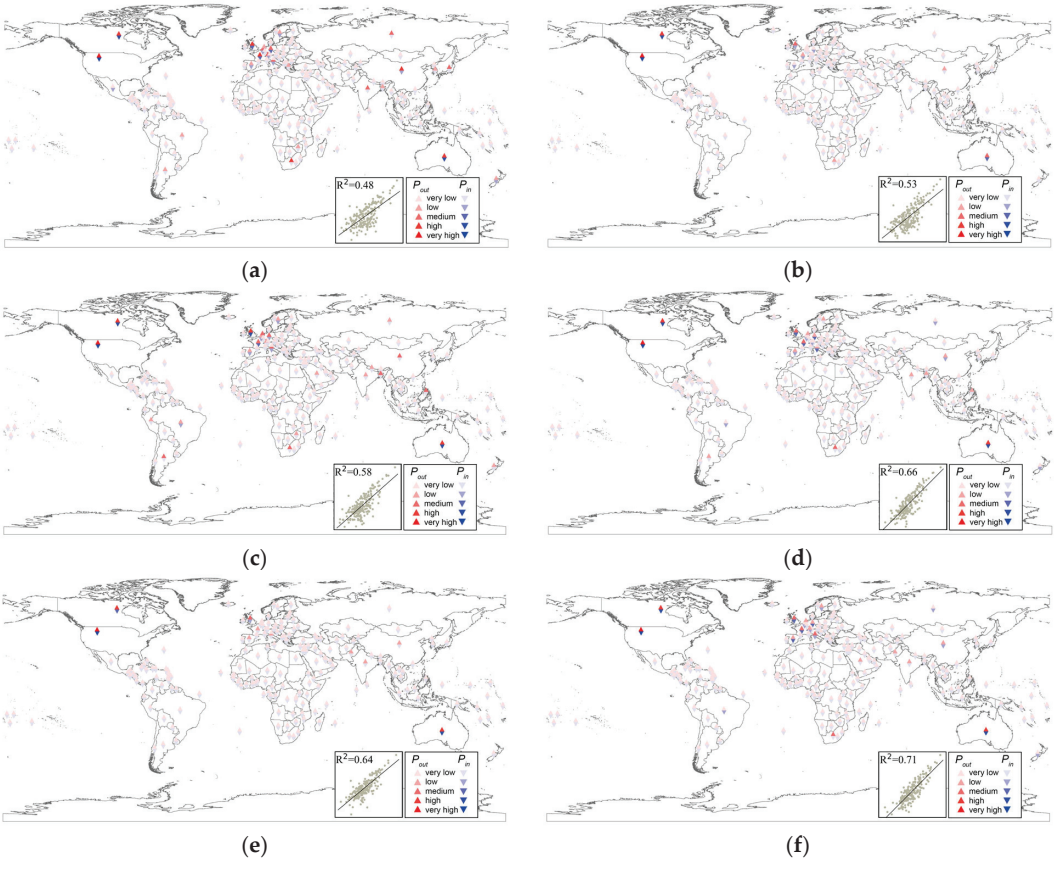


Figure 7. Geographical visualization of bidirectional node attractions. Triangles pointing up and down indicate outward and inward attraction, respectively, and different colors demonstrate different levels of attraction. Correlation plot of P_{out} and P_{in} in log–log coordinates are added. (**a**–**f**) refer to 6 periods.

Some socioeconomic variables and complex network metrics were used to evaluate the feasibility of the attractions. The correlation matrices are shown in Figure 8.

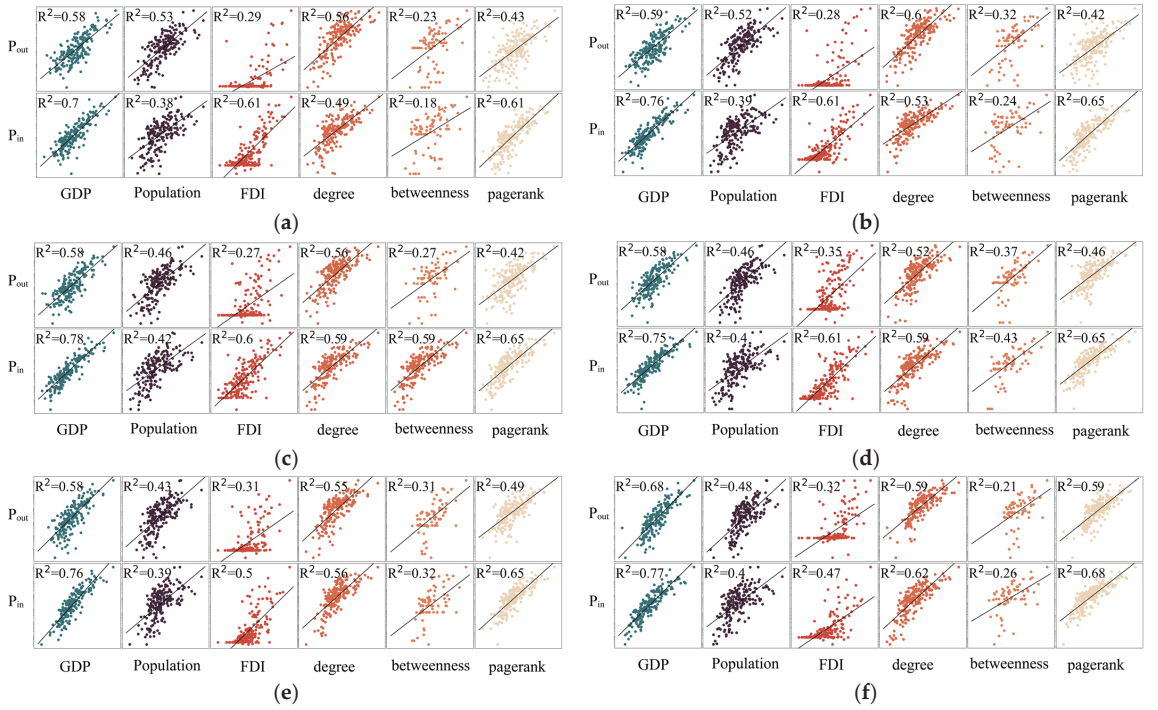


Figure 8. Correlation matrices of node attractions with socioeconomic variables and complex network metrics. P_{out} and P_{in} were analyzed using the GDP, population size, FDI, degree, betweenness, and PageRank score, separately. It should be noted that FDI and degree were both directional and were only analyzed with corresponding directed node attraction. All scatter plots are in log–log coordinates, and (**a**–**f**) refer to 6 periods.

The variable that consistently provided the most accurate interpretation of node attractions for all periods, regardless of the direction, was GDP. The R^2 values were most likely to be the greatest, which suggested that GDP is an effective and comprehensive measure of a country. The correlations between population sizes and node attractions were slightly poorer, and population sizes showed a stronger ability to interpret outward attractions compared to inward attractions. This can be attributed to the fact that population reflects not only opportunities but also competition and is not always the pulling factor. Moreover, although the outward FDI underperformed in most cases, the inward FDI could be a more effective factor in explaining inward attractions than population.

Regarding network metrics, the weighted in-degree and out-degree proved to be the most effective. To test the potential of this metric, they were next used to fit the gravity model, and the goodness of fitness values were 0.409, 0.425, 0.434, 0.437, 0.425, and 0.453 for all networks. This suggested that degrees were still not a good proxy for node attractions. Betweenness, although proven to be a useful measure of centrality, did not appear helpful in this case. It was interesting that the PageRank score performed well, surpassing the population in most periods, particularly in interpreting inward attractions.

To summarize, utilizing a single variable proved insufficient to represent node attractions. The concept of node attractions, which represents the inherent significance of a node, was found to be associated with numerous factors and metrics. Only by using our method can this intrinsic importance be discovered.

3.2.3. Node Position Patterns

The positions of nodes were another important output of our method. We found this position represented the actual migration centroid of a country. Due to the heterogeneous distribution of population and economic activity, this centroid of migration did not match the geometric center. In Figure 9, arrows starting from the geometric center and pointing to the calculated position were drawn, indicating the migration bias in the country. It should be noticed that the searching areas for node positions were set as the bounding box of the administrative area. Full results are listed in Table S2.

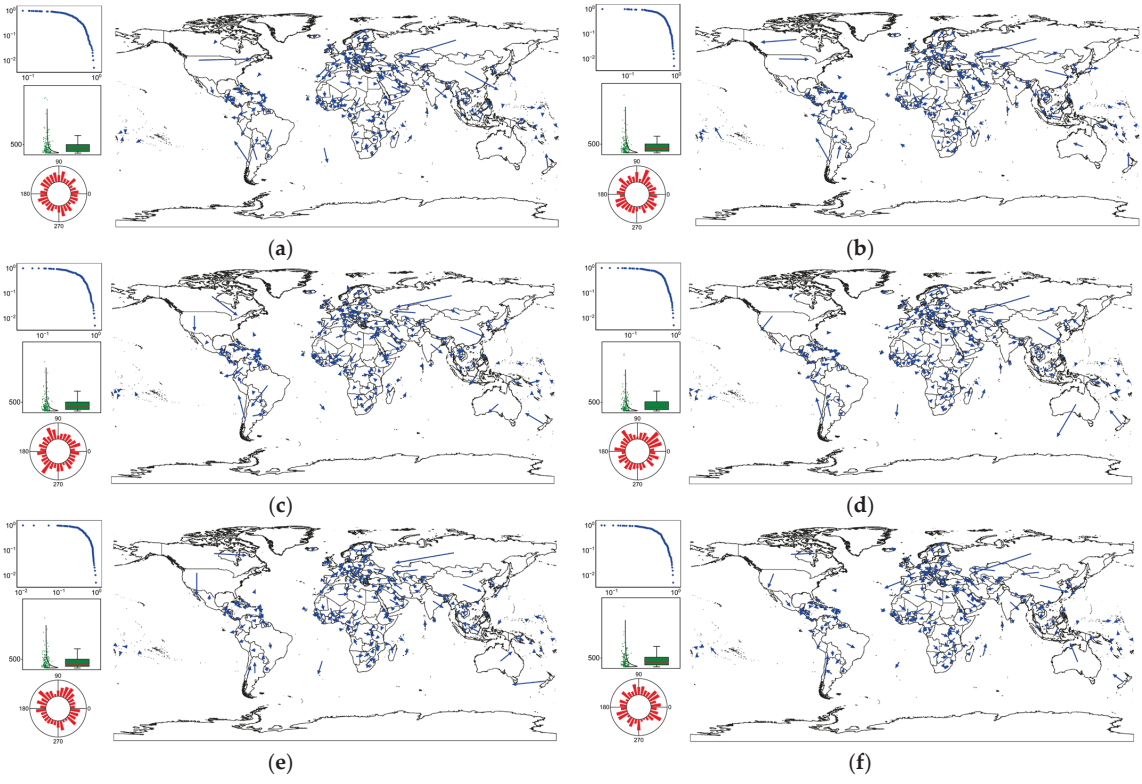
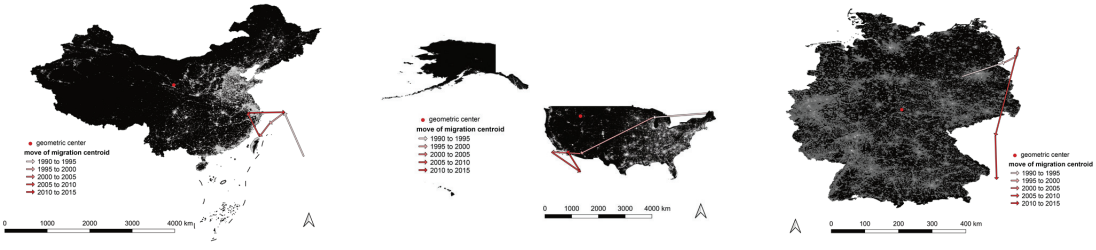


Figure 9. Geographic visualization and statistical analysis for node positions. Blue arrows from geometric centers to migration centroids were drawn on the map. On the left of the map, and from top to bottom, we have (1) the complementary cumulative distribution of the distance from the geometric center, normalized by the scale of the country; (2) the box plot of the distance in kilometers; (3) the distribution of orientation away from the geometric center. (**a**–**f**) refer to 6 periods.

Several conclusions could be drawn from the results. Statistically speaking, the normalized distance from the geometric center followed a power law distribution, over 70% of the distances were between 0.2 to 0.7. The box plots of distance reported a similar result, revealing that the median distance was about 230 km, with about 27% exceeding 500 km. The distributions of orientations away from the geometric center, on the other hand, showed a random distribution.

For different countries, the calculated position revealed different patterns. Three representative countries were selected as examples to illustrate the varying patterns and meanings of migration centroids. Using nighttime light data of 2020 as background, these three countries are shown in Figure 10. (1) China, as a country covering vast territory, has its population concentrated in southeastern coastal areas, and we found the trajectory

of the migration centroid moved around the same area, especially around Shanghai, the financial and foreign trade center of China. Similar countries were Russia (Figure S1a), Egypt (Figure S1b), Argentina (Figure S1c), etc.; these suggested the ability of migration centroids to indicate the imbalanced demography distribution within a country. (2) For the United States, the migration centroids moved across the country from the northeast, where the traditional industrial area was located, to the southwest, where the electronics industry has increased over the years. This example showed that migration centroids can be used to study the imbalanced developing patterns within a country. (3) The migration centroids of Germany always lay in the east part of the country, which was the area with a relatively low GDP; this may indicate that more migration happened in the less wealthy regions of the country. Other countries such as the United Kingdom (Figure S2a) and India (Figure S2b) shared similarities; here, the migration centroids moved to the north and southeast coastal regions, respectively. For these countries, the migration centroids revealed the heterogeneous economic distribution.



(**a**) (**b**) (**c**)

Figure 10. Spatial-temporal patterns of migration centroids of (**a**) China, (**b**) the United States, and (**c**) Germany. Nighttime light data of 2020 were taken as background, and arrows with different colors indicate the movement of the migration centroid in different years.

3.3. Comparative Analysis of Our Method

Next, the accuracy of our method was tested. Compared with different methods, the goodness of fitness of our method is the highest. For the traditional gravity model, we tested the performance of GDP and population as instrumental variables. The results in Table 2 show that GDP and population size can only account for 24–31% of migration, and population always serves as a better factor than GDP. Putting together GDP and population to get a multivariable model, the goodness of fitness elevated slightly. It is interesting that in this case the parameter α_{out} was always bigger than α_{in} for population variables, but for GDP variables it was always the opposite. For example, in 2015, α_{out}^{pop}, α_{in}^{pop}, α_{out}^{GDP}, and α_{in}^{GDP} were 0.389, 0.345, 0.075, and 0.106, which indicated that the population of the source country and the GDP of the target country had a greater influence on migration. This correlated with the common-sense idea that people tend to seek fortune and avoid competition via migration. Our method had also been compared with a reverse gravity method with dummy variables [53]; by introducing O_i and D_j such that $O_i = D_j = 1$ when $G_{ij} > 0$ and $O_i = D_j = 0$ otherwise, Equation (6) can be converted into a linear regression problem:

$$ln(G_{ij}) = \sum ln(P_i^{out}) * O_i + \sum ln\left(P_j^{in}\right) * D_j - \beta\, ln(d_{ij}) + e_{ij}, \quad (7)$$

where e_{ij} is the error. To avoid multicollinearity and overfitting, ridge regression was used. The goodness of fitness in this method was better than that in the gravity model mentioned before. Our method also outperforms an improved gravity model including contiguity, sharing a common official language, colonial relationships, and other factors, as it was reported to reach a R^2 of 0.604 for migration flows between 200 countries [28].

Table 2. The comparison of our method and other methods.

Period	Gravity Model			Reverse Gravity Model	
	GDP	Population	GDP & Population Multivariable	Dummy Variables	Our Method
1990–1995	0.249	0.310	0.327	0.444	0.668
1995–2000	0.249	0.316	0.329	0.454	0.683
2000–2005	0.271	0.319	0.335	0.461	0.682
2005–2010	0.285	0.314	0.335	0.463	0.684
2010–2015	0.305	0.309	0.334	0.464	0.688
2015–2020	0.248	0.308	0.322	0.476	0.696

4. Discussion

By reconstructing the attractions and positions of countries, the gravitational relation that determines migration flow was found. This simple yet effective model could be used to simulate the complex international migration networks. As verified in the geographical preferential attachment model and geographical non-growing network model with vertex weights, this relation may also be the reason for scale-free and small-world properties [57,58].

The distance decay parameter β is an important indicator of the model. This parameter differs in spatial networks of different scales: for intra-urban trips collected from taxi trajectory data and social media check-in data, β is around 1.2–1.5 [59,60]; for inter-urban trips via flights or social media check-in data, β decreases to 0.8–0.9 [30,61]. For migration systems, this value varies from 1 to 4 for different countries [62,63], and it suggests that migration, unlike daily commuting, is more likely to be held back by the cost associated with distance. Here, we found β values were 2.98, 3.06, 2.76, 2.82, 3.03, and 2.92 for each period, respectively, implying a rapid decay in the amount of migration when moving distance increased.

Based on analysis of the results and the comparison with other methods, it can be concluded that the method we proposed is effective and of high accuracy. However, in terms of R^2, there is still room for improvement in this approach. On the one hand, the gravity model has inherent limitations. This model does not take into account factors like cultural or historical relations between countries, which are distance-independent and may influence the interaction. In addition, the radiation model [17], spatial Durbin model [64], and other improvements of the gravity model are widely used in spatial interaction research, which may also be used in the reverse gravity model. On the other hand, international migration as a whole is a complicated system, and there are community and other mesoscale structures in the network. This suggests that a single global model may not be enough, and instead, different models should be fitted to different sub-network structures. For example, if we extract the subgraph of 35 countries of the Organization for Economic Co-operation and Development from the migration network and apply our method to it, the goodness of fitness could reach about 0.78 for all periods, which is significantly superior to the global fitness.

Node attractions from our calculations correlated differently with various socioeconomic variables and network metrics; these six factors could only partly interpret the node attraction. A previous study also pointed out that in spatial interaction networks, degrees are the result of both attractions and locations [65]. This suggests that node attraction might be used as a criterion for evaluating node centrality. There are many centrality measures; however, the lack of ground truths on the importance of nodes makes it difficult to compare different metrics. The node attractions, as the determinant of interactive strength between nodes, participate in the generation of the network, which makes it a persuasive indicator.

Node positions may also have further implications. Using Equation (5), we found that the position of a node might not only be influenced by its domestic heterogeneity but could also be pulled by other nodes of great power. This phenomenon is more commonly seen in small countries. In other words, the meaning behind node positions may not only be the migration centroid, and further effort should be paid to this conception.

5. Conclusions

In this article, we proposed a reverse gravity approach based on genetic algorithm and applied this method to international migration networks from 1990 to 2020. Our method would model the interactive patterns with high accuracy, and the reconstructed node attractions and positions could reveal the characteristics of the country. The node attractions were highly correlated with socioeconomic factors and network metrics, and the node positions outperformed the geometric centers from the perspective of human migration. This method can be used in any other spatial interaction network, which are found extensively in sustainable systems in the real world. Our research presents a tentative solution to the problem of distance calculation when fitting gravity models in migration networks. The limitation of this method is that the node position is influenced both by the domestic heterogeneous distributions of economy and demography and foreign attractions; this complexifies interpretation, especially for small countries. In future research, the implications behind node position should be further investigated, aiming to obtain a more accurate model fitting and a deeper understating of interactive patterns.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16062502/s1, Figure S1: Spatial-temporal patterns of migration centroids of (a) Russia, (b) Egypt, and (c) Argentina. Nighttime light data of 2020 were taken as background, and arrows with different colors indicate the movement of migration centroid in different years; Figure S2: Spatial-temporal patterns of migration centroids of (a) the United Kingdom and (b) India. Nighttime light data of 2020 were taken as background, and arrows with different colors indicate the movement of migration centroid in different years; Table S1: Node attractions; Table S2: Node positions; Table S3 distance away from geometric center.

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References

1. Raymer, J.; Willekens, F.; Rogers, A. Spatial demography: A unifying core and agenda for further research. *Popul. Space Place* **2019**, *25*, e2179. [CrossRef]
2. Lewis, G.J. *Human Migration: A Geographical Perspective*; Routledge: Oxfordshire, UK, 2021.
3. Likić-Brborić, B. Global migration governance, civil society and the paradoxes of sustainability. *Globalizations* **2018**, *15*, 762–778. [CrossRef]
4. Gavonel, M.F.; Adger, W.N.; de Campos, R.S.; Boyd, E.; Carr, E.R.; Fabos, A.; Fransen, S.; Jolivet, D.; Zickgraf, C.; Codjoe, S.N. The migration-sustainability paradox: Transformations in mobile worlds. *Curr. Opin. Environ. Sustain.* **2021**, *49*, 98–109. [CrossRef]
5. Tranos, E.; Gheasi, M.; Nijkamp, P. International migration: A global complex network. *Environ. Plan. B Plan. Des.* **2015**, *42*, 4–22. [CrossRef]
6. Leal, D.F.; Harder, N.L. Migration networks and the intensity of global migration flows, 1990–2015. *J. Ethn. Migr. Stud.* **2023**, *49*, 445–464. [CrossRef]
7. Davis, K.F.; D'Odorico, P.; Laio, F.; Ridolfi, L. Global Spatio-Temporal Patterns in Human Migration: A Complex Network Perspective. *PLoS ONE* **2013**, *8*, e53723. [CrossRef]

8. Fagiolo, G.; Mastrorillo, M. International migration network: Topology and modeling. *Phys. Rev. E* **2013**, *88*, 012812. [CrossRef]
9. Fagiolo, G.; Mastrorillo, M. Does Human Migration Affect International Trade? A Complex-Network Perspective. *PLoS ONE* **2014**, *9*, e97331. [CrossRef]
10. Abel, G.J.; DeWaard, J.; Ha, J.T.; Almquist, Z.W. The form and evolution of international migration networks, 1990–2015. *Popul. Space Place* **2021**, *27*, e2432. [CrossRef]
11. Gao, S.; Liu, Y.; Wang, Y.; Ma, X. Discovering spatial interaction communities from mobile phone data. *Trans. GIS* **2013**, *17*, 463–481. [CrossRef]
12. Li, Z.; Tang, J.; Zhao, C.; Gao, F. Improved centrality measure based on the adapted PageRank algorithm for urban transportation multiplex networks. *Chaos Solitons Fractals* **2023**, *167*, 112998. [CrossRef]
13. Haynes, K.E.; Fotheringham, A.S. *Gravity and Spatial Interaction Models*; Regional Research Institute, West Virginia University: Morgantown, WV, USA, 2020.
14. Oshan, T.M. The spatial structure debate in spatial interaction modeling: 50 years on. *Prog. Hum. Geogr.* **2021**, *45*, 925–950. [CrossRef]
15. Ramos, R. Modelling migration. In *The Econometrics of Multi-Dimensional Panels: Theory and Applications*; Springer: Berlin/Heidelberg, Germany, 2024; pp. 455–478.
16. Ramos, R. *Gravity Models: A Tool for Migration Analysis*; IZA World of Labor; Institute for the Study of Labor (IZA): Bonn, Germany, 2016.
17. Simini, F.; González, M.C.; Maritan, A.; Barabási, A.-L. A universal model for mobility and migration patterns. *Nature* **2012**, *484*, 96–100. [CrossRef]
18. Liu, E.-J.; Yan, X.-Y. A universal opportunity model for human mobility. *Sci. Rep.* **2020**, *10*, 4657. [CrossRef]
19. Zipf, G.K. The P1 P2/D Hypothesis: On the Intercity Movement of Persons. *Am. Sociol. Rev.* **1946**, *11*, 677–686. [CrossRef]
20. Dueñas, M.; Fagiolo, G. Modeling the International-Trade Network: A gravity approach. *J. Econ. Interact. Coord.* **2013**, *8*, 155–178. [CrossRef]
21. Krings, G.; Calabrese, F.; Ratti, C.; Blondel, V.D. Urban gravity: A model for inter-city telecommunication flows. *J. Stat. Mech. Theory Exp.* **2009**, *2009*, L07003. [CrossRef]
22. Liu, J.H.; Zhang, Z.K.; Chen, L.J.; Liu, C.; Yang, C.C.; Wang, X.Q. Gravity Effects on Information Filtering and Network Evolving. *PLoS ONE* **2014**, *9*, e91070. [CrossRef]
23. Anderson, J.E. The Gravity Model. *Annu. Rev. Econ.* **2011**, *3*, 133–160. [CrossRef]
24. Shepherd, B. *The Gravity Model of International Trade: A User Guide*; United Nations ESCAP: Bangkok, Thailand, 2013.
25. Alis, C.; Legara, E.F.; Monterola, C. Generalized radiation model for human migration. *Sci. Rep.* **2021**, *11*, 22707. [CrossRef]
26. Niu, F. A push-pull model for inter-city migration simulation. *Cities* **2022**, *131*, 104005. [CrossRef]
27. Yan, X.Y.; Zhao, C.; Fan, Y.; Di, Z.; Wang, W.X. Universal predictability of mobility patterns in cities. *J. R. Soc. Interface* **2014**, *11*, 20140834. [CrossRef] [PubMed]
28. Ramos, R.; Suriñach, J. A Gravity Model of Migration Between the ENC and the EU. *Tijdschr. Voor Econ. Soc. Geogr.* **2017**, *108*, 21–35. [CrossRef]
29. Shen, G. Reverse-fitting the gravity model to inter-city airline passenger flows by an algebraic simplification. *J. Transp. Geogr.* **2004**, *12*, 219–234. [CrossRef]
30. Xiao, Y.; Wang, F.H.; Liu, Y.; Wang, J. Reconstructing Gravitational Attractions of Major Cities in China from Air Passenger Flow Data, 2001–2008: A Particle Swarm Optimization Approach. *Prof. Geogr.* **2013**, *65*, 265–282. [CrossRef]
31. Abel, G.J.; Cohen, J.E. Bilateral international migration flow estimates for 200 countries. *Sci. Data* **2019**, *6*, 82. [CrossRef]
32. Benveniste, H.; Oppenheimer, M.; Fleurbaey, M. Climate change increases resource-constrained international immobility. *Nat. Clim. Chang.* **2022**, *12*, 634–641. [CrossRef]
33. Petropoulos, F.; Apiletti, D.; Assimakopoulos, V.; Babai, M.Z.; Barrow, D.K.; Taieb, S.B.; Bergmeir, C.; Bessa, R.J.; Bijak, J.; Boylan, J.E. Forecasting: Theory and practice. *Int. J. Forecast.* **2022**, *38*, 705–871. [CrossRef]
34. Mayda, A.M. International migration: A panel data analysis of the determinants of bilateral flows. *J. Popul. Econ.* **2010**, *23*, 1249–1274. [CrossRef]
35. Garas, A.; Lapatinas, A.; Poulios, K. The Relation between Migration and Fdi in the Oecd from a Complex Network Perspective. *Adv. Complex Syst.* **2016**, *19*, 1650009. [CrossRef]
36. Barabási, A.L.; Albert, R. Emergence of scaling in random networks. *Science* **1999**, *286*, 509–512. [CrossRef]
37. Li, Y.L.; Chen, B.; Chen, G.Q. Carbon network embodied in international trade: Global structural evolution and its policy implications. *Energy Policy* **2020**, *139*, 111316. [CrossRef]
38. Clauset, A.; Shalizi, C.R.; Newman, M.E.J. Power-Law Distributions in Empirical Data. *Siam Rev.* **2009**, *51*, 661–703. [CrossRef]
39. Humphries, M.D.; Gurney, K.; Prescott, T.J. The brainstem reticular formation is a small-world, not scale-free, network. *Proc. R. Soc. B Biol. Sci.* **2006**, *273*, 503–511. [CrossRef] [PubMed]
40. Fagiolo, G. Clustering in complex directed networks. *Phys. Rev. E* **2007**, *76*, 026107. [CrossRef]
41. Freeman, L.C. Centrality in Social Networks Conceptual Clarification. *Soc. Netw.* **1979**, *1*, 215–239. [CrossRef]
42. Girvan, M.; Newman, M.E.J. Community structure in social and biological networks. *Proc. Natl. Acad. Sci. USA* **2002**, *99*, 7821–7826. [CrossRef] [PubMed]
43. Jia, T.; Yu, X.S.; Li, X.; Qin, K. Identification and analysis of urban influential regions using spatial interaction networks. *Trans. GIS* **2021**, *25*, 2821–2839. [CrossRef]

44. Brandes, U. A faster algorithm for betweenness centrality. *J. Math. Sociol.* **2001**, *25*, 163–177. [CrossRef]
45. Brin, S.; Page, L. The anatomy of a large-scale hypertextual Web search engine. *Comput. Netw. Isdn Syst.* **1998**, *30*, 107–117. [CrossRef]
46. Masuda, N.; Porter, M.A.; Lambiotte, R. Random walks and diffusion on networks. *Phys. Rep. Rev. Sect. Phys. Lett.* **2017**, *716*, 1–58. [CrossRef]
47. Barbosa, H.; Barthelemy, M.; Ghoshal, G.; James, C.R.; Lenormand, M.; Louail, T.; Menezes, R.; Ramasco, J.J.; Simini, F.; Tomasini, M. Human mobility: Models and applications. *Phys. Rep. Rev. Sect. Phys. Lett.* **2018**, *734*, 1–74. [CrossRef]
48. Morley, C.; Rosselló, J.; Santana-Gallego, M. Gravity models for tourism demand: Theory and use. *Ann. Tour. Res.* **2014**, *48*, 1–10. [CrossRef]
49. Windzio, M. The network of global migration 1990-2013 Using ERGMs to test theories of migration between countries. *Soc. Netw.* **2018**, *53*, 20–29. [CrossRef]
50. Wang, Y.Q.; Luo, H.; Shi, Y.Y. Complex network analysis for international talent mobility based on bibliometrics. *Int. J. Innov. Sci.* **2019**, *11*, 419–435. [CrossRef]
51. Okelly, M.E.; Song, W.; Shen, G.Q. New Estimates of Gravitational Attraction by Linear-Programming. *Geogr. Anal.* **1995**, *27*, 271–285. [CrossRef]
52. Shen, G.Q. Estimating nodal attractions with exogenous spatial interaction and impedance data using the gravity model. *Pap. Reg. Sci.* **1999**, *78*, 213–220. [CrossRef]
53. Song, W. Nodal Attractions in China's Intercity Air Passenger Transportation. In Proceedings of the 29th Annual Applied Geography Conference, Tampa, FL, USA, 11–14 October 2006.
54. Garg, H. A hybrid PSO-GA algorithm for constrained optimization problems. *Appl. Math. Comput.* **2016**, *274*, 292–305. [CrossRef]
55. Holland, J.H. Genetic algorithms. *Sci. Am.* **1992**, *267*, 66–73. [CrossRef]
56. Tinbergen, J. *Shaping the World Economy; Suggestions for an International Economic Policy*; Twentieth Century Fund: New York, NY, USA, 1962.
57. Manna, S.S.; Sen, P. Modulated scale-free network in Euclidean space. *Phys. Rev. E* **2002**, *66*, 066114. [CrossRef] [PubMed]
58. Masuda, N.; Miwa, H.; Konno, N. Geographical threshold graphs with small-world and scale-free properties. *Phys. Rev. E* **2005**, *71*, 036108. [CrossRef]
59. Liu, Y.; Kang, C.; Gao, S.; Xiao, Y.; Tian, Y. Understanding intra-urban trip patterns from taxi trajectory data. *J. Geogr. Syst.* **2012**, *14*, 463–483. [CrossRef]
60. Noulas, A.; Scellato, S.; Lambiotte, R.; Pontil, M.; Mascolo, C. A tale of many cities: Universal patterns in human urban mobility. *PLoS ONE* **2012**, *7*, e37027. [CrossRef]
61. Liu, Y.; Sui, Z.; Kang, C.; Gao, Y. Uncovering patterns of inter-urban trip and spatial interaction from social media check-in data. *PLoS ONE* **2014**, *9*, e86026. [CrossRef]
62. Stillwell, J.; Bell, M.; Ueffing, P.; Daras, K.; Charles-Edwards, E.; Kupiszewski, M.; Kupiszewska, D. Internal migration around the world: Comparing distance travelled and its frictional effect. *Environ. Plan. A Econ. Space* **2016**, *48*, 1657–1675. [CrossRef]
63. Bernard, A.; Rowe, F.; Bell, M.; Ueffing, P.; Charles-Edwards, E. Comparing internal migration across the countries of Latin America: A multidimensional approach. *PLoS ONE* **2017**, *12*, e0173895. [CrossRef] [PubMed]
64. Durbin, J. Estimation of Parameters in Time-Series Regression-Models. *J. R. Stat. Soc. Ser. B Stat. Methodol.* **1960**, *22*, 139–153. [CrossRef]
65. Liu, Y.; Gong, L.; Tong, Q. Quantifying the Distance Effect in Spatial Interactions. *Acta Sci. Nat. Univ. Pekin.* **2014**, *50*, 526–534.

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A Neopragmatic Perspective on the Processual Nature of Landscape—Coastal Land Loss in Louisiana in the Context of Scientific Findings, Social Patterns of Interpretation, and Individual Experience

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Abstract: The changes on the Louisiana coast due to land loss can be understood as a process, and the social construction of these processes is highly complex. Due to this complexity, we will examine these social patterns of interpretation as well as individual experiences of coastal land loss in Louisiana within a neopragmatic meta-theoretical framework using several methods, data, researcher perspectives, forms of representation, and theories, with a special focus on the construction of coastal land loss by the media. For this purpose, comments below a YouTube video on a hurricane event on Grand Isle, Louisiana, as well as on-site interviews with people affected by coastal land loss, were qualitatively analyzed. The results were interpreted with the help of various theories such as the theory of three landscapes, Dahrendorf's conflict theory, Bourdieu's theory of social capital, and Luhmann's autopoietic systems theory. The research reveals patterns of interpretation, categorization, and evaluation of processes from an internal and external perspective that are highly morally charged.

Keywords: neopragmatism; three landscapes theory; autopoietic systems theory; symbolic capital; conflict theory; coastal land loss; qualitative content analysis; Louisiana; effects of climate change

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1. Introduction

Changes in landscape in general, and on the Louisiana coast in particular, are often understood as 'transformation' (see, for example, [1–4]). In this article, we understand change as process, as a special case of transformation. Addressing the processuality of landscapes means emphasizing the goal-directedness but also the active element of influencing the material foundations of landscape; transformation can also be understood passively and undirectedly [5]. In addition, the concept of process focuses more strongly on the context-dependency of changes than the more general concept of transformation is able to do [6,7]. Landscape processes are contextualized on and between three levels: The first level refers to the physical space interpreted as landscape, the second to that of individual consciousness, and the third to that of socially shared patterns of interpretation, evaluation, and categorization. Even this brief outline of the complexity of landscape processes makes it clear how little landscape, especially if its temporal dynamics are to be examined, can be understood from the perspective of a single theory. In this respect, we will approach the topic of coastal land loss in Louisiana in the context of scientific findings, social patterns of interpretation, and individual experience in a neopragmatic way. In brief, neopragmatism combines the tradition of American pragmatism with the tradition of the continental utopian philosophy of language. In this work, it forms a metatheoretical basis. Against the background of considerations of suitability, it enables a combination of different theories, methods, researcher perspectives, data, and forms of representation. This paper is an expression of a larger research program (see, e.g., [8–10]) whose aim is to

make philosophical neopragmatism available to regional geography in order to provide it with a theoretical framework that integrates social constructions, individual contributions, and material foundations. In this paper, we focus on the social resonances of land loss in Louisiana (Louisiana being the space in which the neopragmatic research program is tested).

Our article pursues the following objectives. At the level of the research object, our aim is to identify different patterns of interpretation, categorization, and evaluation of landscape processes in the context of coastal land loss in Louisiana and examine their interrelationships. On the level of landscape theoretical research, our aim is to understand the differentiation of landscape-related constructions and thus contribute to the understanding of the social construction of landscape as well as the individual experience of landscape. On a meta-theoretical level, the aim of our article is to test the suitability of (further) neopragmatic combinations of theories. This article aims to contribute to the understanding of the perception, interpretation, and evaluation of landscape processes that are partly caused by climate change, which is commonly considered to be at least partly based on the unsustainable behavior of a society.

In Section 2, neopragmatism as the meta-theoretical framework of this paper and the various theories used are examined. Section 3 then introduces the theory of the Three Landscapes derived from Popper and Section 4 deals with the construction of the world through media. In order to gain a better overview of land loss in Louisiana, the processes causing coastal land loss are then explained in more detail in Section 5. In Section 6, we will explain the research design before going into detail about the empirical findings in Sections 7 and 8. Section 9 discusses the analysis with reference back to theory, which is followed by Section 10, offering a final conclusion.

2. Neopragmatic Metatheoretical Framework and Theoretical Perspectives

Neopragmatism forms the meta-theoretical basis of the research program for the neopragmatic justification of dealing with regional geographies. This is necessary because triangulations of theories, methods, data, researcher perspectives, and the integration of people with different degrees of professionalism, as well as the presentation of results, are carried out.

In philosophy, neopragmatism is associated in particular with Richard Rorty [11–16], but also with Hilary Putnam [17–19] (detailed introductions to neopragmatism can be found in [20–24]). Neopragmatism is based on American pragmatism, which favors practical criteria over abstract theory. The criterion for 'truth' is the success of ideas, "interests, values and goals" [25] (p. 1544). Truth becomes what "happens to an idea. It becomes true, it is made true by events" [26] (p. 67). This pragmatic understanding of truth ignores normative/moral meanings ('good' vs. 'evil') (cf. [27]). With his concept of 'warranted assertibility', John Dewey specifies the pragmatic concept of truth [28,29]: Dewey calls 'true' that which has already been elaborated upon by means of scientific methods and results and that which can be described as valid by means of the methods and results to be developed in the future (cf. [29,30]). An idea that—as will become clear later—also characterizes neopragmatism.

Neopragmatism draws on the basic features of pragmatic thinking (in particular the idea of suitability, but also skepticism towards the idea of definitive knowledge). However, it expands these basic features to include linguistic theory and, in part, post-structuralist approaches [31]. This broadening of the perspective of neopragmatism is summarized by Barnes [25] (p. 1543) as follows: "In addition to the usual American suspects (Rorty's favorite was Dewey), his worldview also included European philosophers such as Wittgenstein, Heidegger, Foucault and Derrida". Rorty's turn towards language theory is also evident in his replacement of the concept of 'truth' with 'redescription'. This term not only reveals the constitutive meaning of language but also the contingency of the world [31]. Against the background that neither knowledge of nature nor moral convictions or insights into social facts represent the image of any kind of 'reality' [31], the concept

of 'discovery' (of a context) also becomes obsolete. Rorty replaces it with the concept of 'invention' [12,13,31]. With recourse to the pragmatic tradition, fundamental dichotomous differences such as lie/truth or appearance/reality are replaced by the understanding of useful or less useful ways of speaking [32]. In the tradition of Dewey, Rorty understands ideas (i.e., also scientific theories) as instruments or tools that are intended to enable people to access them in a way that enables them to solve problems [33,34].

Contingency, one, if not the central concept in neopragmatism as coined by Rorty, denotes that which is neither necessary nor impossible. For Rorty, contingency stands "at one end of a series of opposites, at the other end of which are terms such as *necessary in different ways*, *essential*, *immanent* or *unconditional*" ([35] (p. 958), emphasis in original). Neopragmatism is associated with the insight "that [one's own] central beliefs and needs are contingent" [36] (p. 14). This has implications not only for philosophy: "For it is not enough to recognize that a multitude of other vocabularies exist alongside one's own; rather, one must relate this observation to anti-foundationalist conceptions of language, man and the world in order to be able to make the diagnosis of contingency" [37] (p. 158). Rorty [12] understands 'vocabularies' in reference to Wittgenstein's [38] 'language games', as common platforms of social justification practice. Justification, in turn, is contextually bound to the vocabulary of a concrete linguistic community [21]. As a result of the diversity of linguistic communities, there is a need for the justification of one's own approaches to the world [39], whereby 'justification' is not to be understood as 'proof' or 'substantiation' but as "developing reasons that speak in favor of this conviction" [40] (p. 259).

The quality of redescriptions is measured by their suitability, which highlights the pragmatic roots of his theory. Accordingly, redescriptions—whereby the connection to Rorty's central concept described above becomes clear—"contribute to demonstrating the sheer contingency of our concepts and perspectives. Once a person recognizes the contingency of their inherited definitive vocabulary and other definitive vocabularies, they are more inclined to experiment with different descriptions or conceptions of themselves and others, as well as alternative ways of living" [41] (pp. 462–463). Redescription becomes necessary when a 'time-honored' vocabulary has become questionable. Questionability is measured by the fact that a vocabulary is no longer able to fulfill its claim to suitability [13]. Furthermore, redescriptions can be understood as an attempt to deal with unsolvable problems, unsolvable conflicts, or unsolvable anomalies, in short, to regulate how to deal with them without producing a fundamental and universally valid solution. Old vocabularies are not simply shelved in redescriptions but form the basis of a new 'fabric'. Redescription is ultimately a process of reweaving 'traditional' vocabularies into a new vocabulary [35]. Remnants of old vocabularies that prove to be suitable are thus recycled [13,35]. The quality of the redescription is measured, firstly, by its current suitability to interpret the 'world'. Secondly, the quality of a redescription is measured by its openness to become part of the fabric of a future redescription [13,35].

Scientific redescriptions can be understood as an attempt to generate a suitable and contingent interpretation of complex questions. The focus on suitability, the tool character of theories, and the anti-fundamentalist attitude of neopragmatism suggest a combination of theoretical perspectives (but also methods, researcher perspectives, data, etc.) when dealing with complex questions (for more details, see [8–10,42,43]). The combination of theories is measured on the one hand by their expected suitability for redescription (to be confirmed in the research process) and on the other hand by their acceptance of contingency. The latter criterion consequently excludes essentialist understandings of the world from integration into a neopragmatic theoretical framework.

Neopragmatism forms the basis for combining theories (including methods, data, etc.) that have different claims to validity, even those that are in competition with each other. As explained above, it is about generating useful redescriptions of the world, following the pragmatic legacy of neopragmatism to pursue self-contained science that is consistent in itself, based on principles designed for eternity. Neopragmatism is interested in making suggestions for the contingent interpretation of the world with the aim of contributing to

solving problems (an approach that can also be seen in Popper, e.g., [44])—in our case, the social interpretation of land loss in Louisiana.

In this study, we draw on three theories: firstly, Niklas Luhmann's autopoietic systems theory; secondly, Pierre Bourdieu's theory of symbolic capital; and, thirdly, Ralf Dahrendorf's conflict theory. The autopoietic systems theory of Niklas Luhmann [45,46]—in the tradition of classical social science systems theories—assumes that the social world can be divided into social systems that are entrusted with specific tasks for society as a whole, such as the regulation of scarcity for the economy, fundamental decisions of social development for politics, the production of knowledge for science, ensuring compliance with legal standards for the legal system, and so on. Luhmann now assumes that these social subsystems are only able to construct the world according to their system codes and only do so when they are set in resonance. For example, landscape processes only become relevant for the economic system when money is gained/lost, for the political system when this enables a gain in power or threatens a loss of power, for the scientific system when (publishable) knowledge can be generated, etc. In our context, this approach is interesting because it allows access to the specific constructions of coastal land loss in the individual social subsystems.

This view is supplemented by Pierre Bourdieu's symbolic capital approach [47,48]. He assumes that three relevant forms of capital are traded in society: economic capital (which can be exchanged for money), social capital (resilient social networks), and cultural capital (education, educational qualifications, and works of art). On the one hand, these capitals can be exchanged for each other; on the other hand, together, they form the basis of symbolic capital, by which a person's position in society is measured. Economic, social, and cultural capital are neither equally distributed in society nor, as a rule, individually—so people with a high level of cultural capital do not necessarily also have a high level of economic capital (a frequently cited example is the cab driver with a doctorate in philosophy) and vice versa (classic here: the nouveau riche). This approach by Bourdieu—in combination with a-, b-, and c-modal construction patterns of landscape—serves to examine distinctive communication processes in the context of the communicative construction of coastal land loss in Louisiana.

The third theoretical approach to the communicative construction of coastal land loss in Louisiana is Ralf Dahrendorf's conflict theory [49–51]. In short, Dahrendorf assumes that social conflicts are a normality in all societies and have a productive potential. However, they can only develop this productive potential if they are regulated and not fought until bloodshed. In order to be able to settle conflicts productively, he formulates a number of prerequisites: Parties to the conflict must be as organized as possible, recognize the legitimacy of the position of the other party in the conflict, and comply with the procedural rules for settling the conflict, and there must be a third party who, should no agreement be reached between the parties of the conflict, is in a position to end the conflict through a powerful intervention (for Dahrendorf, this function is usually assigned to the state). With the help of Dahrendorf's conflict theory, we want to trace the lines of conflict in the context of coastal land loss in Louisiana and assess whether and to what extent the possibility of a productive conflict settlement exists.

Before we discuss the different methods and data types, we will address the analytical approach of our study, namely, the theory of the Three Landscapes.

3. The Theory of the Three Landscapes as an Analytical Approach

The theory of the Three Landscapes is developed from Karl Popper's Three Worlds theory [52–54]. The development of the theory of the three landscapes has been explained and justified in detail elsewhere (e.g., in [9,55–57]). It has also proven its worth in landscape research on various occasions (e.g., in [58–61]). It offers an analytical framework that contributes to understanding the complexity of the concept of landscape. Such a differentiation is necessary because the concept of landscape—even in specialist terminology—has a large

'semantic yard'. It unites aesthetic, ontological, and moral constructions, blending the level of material objects with that of social and individual construction.

Popper divides the world into three levels [52–54]: world 1 comprises the world of material objects, world 2 is that of individual consciousness, and world 3 is that of cultural content. Worlds 1 and 3 are connected via world 2. Three spaces can be developed accordingly: space 1 refers to material objects in a spatial arrangement, space 2 to individual ideas of space, and space 3 to socially shared ideas of space. Landscapes 1, 2, and 3 can also be formed analogously. The difference between space and landscape lies on the one hand in the constitutive level: individual spatial ideas arise from the elementary experience of space 1, whereas landscape is a societal synthesis guide; the ideas of landscape 3 are conveyed to landscape 2 through socialization and then projected into space 1 as landscape 1. On the other hand, landscape can also be understood as a subset of space, so landscape 1 consists of a socially preformed selection of objects of space 1 that are subjected to a synthesis (blades of grass are generally not understood individually as part of landscape but after a previous synthesis to 'meadow'). In addition, the understanding of landscape 3 extends beyond the boundaries of space 3 when the term 'landscape' is used metaphorically to describe, for example, the synopsis of 'something', such as political landscape, religious landscape, or educational landscape.

In the following, the general Three Worlds Theory is operationalized for landscape research. In doing so, it follows a tradition that—with regard to a more general spatial theory—has been pursued for some time, particularly in social geography (see, among others, [62–68]). The theory of the Three Landscapes forms the differentiating basis of further investigation. On the basis of the theory of the Three Landscapes, the following section will analyze whether the material dimension of landscape is addressed, that of individual attention, or that of social construction. The theory of the Three Landscapes was developed elsewhere; it is a hermeneutically derived understanding, which is derived on the one hand from the sociology knowledge of Peter Berger and Thomas Luckmann [69,70], with recourse to the social phenomenology of Alfred Schütz [71,72], and on the other hand from numerous empirical studies (qualitative and quantitative; see, e.g., [73–78]). It forms the basis for further explanations of landscape theory. As the derivation and justification of the theory have been explained in detail elsewhere (see above), we will only summarize it briefly here.

Landscape 3—as the constitutive level of landscape—is culture-specific (see, among others, [79–81]) and socially differentiated. In the following, we will deal with the social differentiation of landscape 3 and subsequently also landscape 2 and landscape 1. The available patterns of interpretation, categorization, and evaluation in relation to landscape are socially distributed differently. This unequal distribution can be assigned to different modes of landscape construction. The a-modal mode of construction refers to the 'native normal landscape'. This is created in childhood and adolescence under the guidance of significant others (parents, siblings, etc.; [82]) in the experience of space 1, especially in the surroundings of the parental home. This is constructed as 'normal'—regardless of whether it corresponds to stereotypical aesthetic ideas or not. The normative expectation of space 1, interpreted as landscape 1a, can be described as stability. The b-modal landscape construction is that of the 'commonsense landscape'. The formation of this understanding of landscape takes place primarily in youth, and is not completed in later life, but generally takes place throughout life. It is based on content from school lessons, internet videos, illustrated books, television content, etc., and includes aesthetic and increasingly also ecological stereotypes. In normative terms, the claim to space interpreted as landscape 1b is linked to compliance with these stereotypes (see, for example, [83–85]). The c-modal landscape reference is based on 'expert-like special knowledge', which is acquired in particular through specialized studies. These special bodies of knowledge are strongly linked to the various specialist traditions. The c-modal construction of landscape is, firstly, normatively strongly linked to the fit of space 1 to the technical requirements of landscape 1c; secondly, it is also characterized by strong paradigmatic interpretative competitions; and, thirdly, it is strongly

oriented towards innovation (more on this: [86–90]). The b-mode is characterized by selectively adopting patterns of interpretation, categorization, and evaluation of landscape from the c-mode. The selectivity results in particular from a reduction of statements while (largely) ignoring complex technical contexts, theoretical foundations, and methodological considerations (more on this: [91–94]).

These statements represent a clear abstraction. They serve to facilitate an understanding of the social construction of landscape and are generated under neopragmatic conditions in order to be absorbed into more suitable approaches. Approaches, for example, that take greater account of cultural influences.

This differentiated modal construction of landscape can be summarized as follows. Highly different landscapes 1a, 1b, and 1c are synthesized into space 1, whereby the landscapes in a-mode clearly differ from one another as a result of individual formation. The landscapes in the c-mode also differ very clearly from one another as a result of disciplinary ties as well as different paradigmatic orientations. As a result of the general internet-based availability of c-modal content, among other things, b-modal access to landscape is also differentiated—and this is certainly interest-driven—which we will also illustrate in the presentation of our empirical results. Before we turn our attention to the social construction of coastal land loss, we will—since we have a strong focus on social media communication—take a look at the mechanisms of the construction of the world by mass media in the following section.

4. The Construction of the World by the Media—Introductory Remarks

The influence of the media on our perception of the world has been the subject of scientific and, in particular, geographical studies for some time (among others, [95–115]). At the center of spatial-scientific studies of the media are often, therefore, questions regarding the influence on and questioning of constructions of reality, the creation of world views by the media, and the geographies created by the media [98,116] (p. 89). This article is based in part on the interpretation of mass media communication and the corresponding construction of the section of the physical environment discussed. Therefore, in the following paragraph, some overview-like remarks on the media construction of the world are given, which should lay the foundation for further analysis.

Mass media are ascribed a central role in the construction of the world because "[t]he mass media play a profoundly significant role in the appropriation and interpretation of the meanings of social reality. They have the capability to shape conceptions of our physical, economic, political, and social environments" [117] (p. 194). According to constructivist understandings of the world, media already provide "mediatized, often artificially produced images of reality through selection, perspective, coloring, lighting, language and commentary" [118] (p. 14) and are not in a position to convey objectivity or even 'reality'. This is why media are often referred to as "worldview generators" [116] (p. 89) or "reality apparatuses" [119] (p. 98). Sometimes the influence on the viewing expectations of the spaces about which media impressions are conveyed goes so far that the media-constructed viewing expectations and the space that can be physically found on site can no longer be reconciled (see also [120]). Luhmann [121] (pp. 14–15) speaks with regard to the 'reality' of the mass media of a "doubling of reality" that takes place within the system of the mass media through observing their operations. He describes the analysis of mediated information as the "observation of observers" [121] (p. 154) so that the reality of the mass media only becomes apparent through a "second-order observation" [121] (p. 153). Of particular interest here are the links between media, space, society, and the individual because media communication attempts to address society as a whole and bring its social subsystems into resonance [121].

5. Coastal Land Loss in Louisiana—Some Basic Features

Before turning to the media and individual constructions and perceptions of coastal land loss in Louisiana, we will give a brief overview of the processes causing coastal land

loss (for a more detailed elaboration, see [91,113,122–127]). In this section, we largely refer to scientific findings. These are mostly derived from a basic positivist perspective. However, they have proven their usefulness in dealing with coastal land loss in Louisiana; after all, humans are somatic beings [128,129]. The aim of neopragmatic landscape research is to enable an integrative consideration of materiality, individual approaches, and social constructions. In this respect, positivist studies are also used as a substrate for the investigation of landscape construction processes.

The processes leading to coastal land loss (space 1) are manifold. Some are beyond the control of humans; others are caused by humans and result from specific systemic logics of the utilization of space 1.

The glacial isostatic subsidence caused by the melting of the North American inland ice after the last glacial cannot be influenced by humans. As a result, coastal space 1 of Louisiana is subsiding as the lithosphere relieved in the north is now rising [130]. The subsidence process is intensified by the additional load from Mississippian sediments. These represent an additional regional load on the lithosphere, pushing it into the asthenosphere [122,131]. This initially loosely deposited sediment is also subject to compaction, causing the earth's surface to sink. In addition, parts of the poured sediments tend to become mobile under load. This leads to displacement towards the Gulf of Mexico but also to the formation of salt diapirs [131–133]. The dissolution of the salt in these diapirs in turn results in the subsidence of overlying sediments.

However, the processes leading to Louisiana's coastal land loss are also secondary consequences of human activity. Extensive levees were constructed along the Mississippi River, particularly to prevent flooding. However, these also prevent the extensive sedimentation that accompanies the floods. Accordingly, a process that had compensated for the subsidence of the regional earth's surface for a long time is missing [134]. In order to create suitable areas for agricultural use but also for infrastructure, industrial uses, and settlements, a drainage system was developed to drain land. Drainage, in turn, accelerates subsidence in mineral soils and oxidation in organic soils. Both processes lead to a lowering of the ground surface [133,135]. This subsidence is further increased with high loads (such as large buildings like in downtown New Orleans) [131,133]. The extraction of oil and gas (characterized by c-modal access) is associated with a pressure loss in the reservoir rock. The extraction of raw materials also leads to the ingress of water into salt diapirs. Both processes lead to surface subsidence [133,136]. In order to transport material, technical equipment, and people on the one hand and oil and gas on the other, the coastal region of Louisiana has been crisscrossed by countless pipelines and canals (space 1c). This is associated with the intrusion of salt water, which disturbs the autochthonous vegetation, vegetation that has already been damaged by invasive species (such as Roseau scale insects) [137,138]. Not least, these processes result in the loss of buffer zones that offer protection from approaching hurricanes from the Gulf of Mexico—the frequency and strength of which are expected to increase further as a result of anthropogenic climate change (see, e.g., [139])—before they hit the mainland and inhabited areas. The result is ever greater destruction and a greater reach of the hurricane inland. However, the strongest effects are felt on the Barrier Islands on the Gulf of Mexico, over which hurricanes and storm surges pass almost unchecked—and thus contribute to further erosion through strong waves and squalls (among others, [1,137,140–143]). These processes make the Louisiana coast particularly vulnerable to the consequences of anthropogenic climate change. This applies not only to sea level rises but also to the predicted increase in the number and strength of hurricanes (space 1 with effects on spaces 2 and 3; [122]).

All in all, these various processes have resulted in high amounts of land loss on the southern Louisiana coast. For example, the relative sea level rise in the Gulf of Mexico resulted in an annual land loss on the southern coastal area of Louisiana of approximately 77 km^2 (30 mi^2) in the years between 1978 and 2000 alone [1]. In total, sea levels at the northern coast of the Gulf of Mexico are projected to rise from 0.34 cm to 1.9 m by the end of this century relative to that of the beginning of the twenty-first century [139,144]. These

projections would entail a further loss of coastal land until the end of the century between 2188.97 km^2 and up to 5875.27 km^2 (which equals between 9% and up to 24% of the wetland area calculated in 2007; [144,145]). Resulting from the processes of coastal land loss, the Coastal Protection and Restoration Authority of Louisiana is expecting annual damages between USD 15.2 billion up to USD 24.3 billion as well as annual structural damages between 14,000 and 22,000 structure equivalents within the next 50 years without protective and restorative measures [146]. Figure 1 shows that, according to a 2017 projection by the Coastal Protection and Restoration Authority of Louisiana (CPRA), even more areas of Louisiana's coastal region are projected to disappear within the next 50 years [147,148].

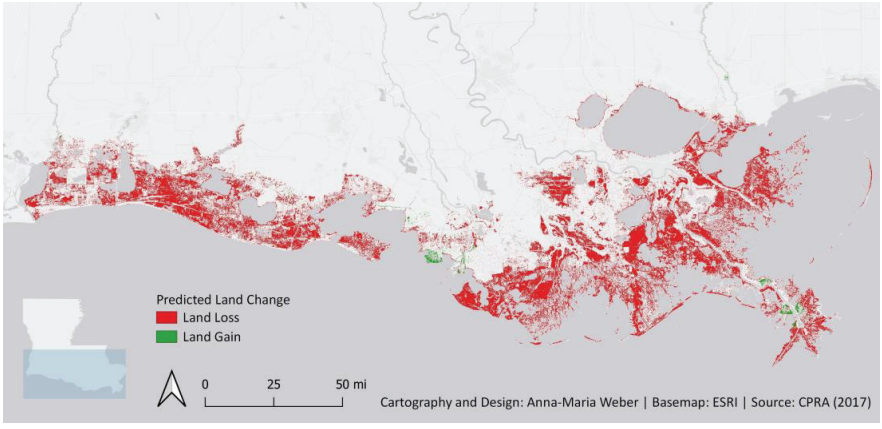


Figure 1. The map shows the predicted massive land loss within the next 50 years (own representation based on [147]).

6. Research Methods

In accordance with the neopragmatic meta-theoretical basis of this article, we not only relied on the integration of different theoretical foundations—as was made clear in the previous sections—but also approached the object of research empirically by means of a triangulation of methods and data. In order to identify the different patterns of interpretation, categorization, and evaluation of landscape processes in the context of coastal land loss, examine their mutual relationships, and understand the differentiation of landscape-related constructions, we relied empirically on two approaches and research objects. We examined interviews and conversations conducted on-site in southern Louisiana as well as the comments of a media discussion in response to a topic-related YouTube video. Using these two data corpora, the individual patterns of interpretation and construction could be detected and categorized particularly well. In order to do justice to the amount and density of information in the statements and result in categorization of the statements, we methodically approached them using qualitative content analyses according to Mayring [149] and Kuckartz and Rädiker [150]. The reason for this is that we tried to discover patterns of interpretation, for which a qualitative approach was suitable since qualitative research is "providing process-based insights, understandings of the lived experience of different conditions, and generating possible causal explanations for phenomena" [151] (p. 5). Qualitative methods do not aim to be representative [152]. However, in order for qualitative research not to be anecdotal and unscientific, three conditions should be met according to Cope and Hay [151]. These include the triangulation of different data and methods, which is also the basis of the neopragmatic approach that we pursue in this work. The second dimension is transferability, which means that the "goal of the production of knowledge is to contribute to broad understandings of the world" [151] (p 11). Since there is already research on the topic, we will address later in the discussion how our study contributes to the current state of research. Ultimately, the third dimension of good qualitative research is

that of transparency, i.e., the awareness of the presence of biases and critical self-reflection, which we achieve through our disclosure of methods including their disadvantages [151]. Consequently, the aim of this paper is to understand the different perceptions and interpretations of individuals based on inductive categories in an interpretative and understanding way. The opportunity offered by qualitative methods lies in a sensitivity to precisely this diversity and differentiation that exist in society (among others, [153]). The use of two different sets of data as well as different ways of collecting and interpreting them (methods as well as data triangulation) allowed us to investigate our main research aim—how the coastal land loss in Louisiana is precepted and interpreted by different individuals (affected as well as not-affected ones)—from different perspectives. The exact procedures and application of the methods are emphasized in more detail in the following two sections.

6.1. Qualitative Content Analysis of YouTube Comments on the Media Discussion about Coastal Land Loss in Louisiana

The comments under a YouTube video were used to examine the media construction of coastal land loss. The possibility of expressing oneself more freely through anonymization on social media [154] as well as the increased importance of online media in recent years [155] make the study of YouTube comments an interesting subject of research. YouTube comments also provide the opportunity to access a large volume of publicly available data [156] in which people's opinions and reactions are shared and a wide variety of topics are discussed.

The YouTube video was selected via the YouTube search query "Hurricane Ida Grand Isle". Grand Isle is a permanently inhabited barrier island located in Louisiana's Jefferson Parish [157] that, due to its high exposure to storm surges and hurricanes, is confronted with particularly strong erosion activities [158–160]. The Coastal Protection and Restoration Authority (CPRA) assumes that Grand Isle is one of eleven parishes in Louisiana that will be uninhabitable in the coming decades [161].

In order to analyze the media construction of the coastal land loss on Grand Isle in a targeted manner, the video was selected according to the following criteria:

1. Spatial criterion: Since the situation on Grand Isle is to be addressed, only videos from Grand Isle were considered.
2. Time criterion: The time frame was defined broadly in the selection in order to include both the event of the hurricane itself and its consequences. This means that videos were also included in the selection in which, for example, the build-up to Hurricane Ida or the situation a few months after the event was discussed.

Based on these selection criteria, several videos could be considered. Even if the number of cases of qualitative studies was much less significant than that of quantitative designs [152], the selection of the video still fell on the one with the largest number of comments, thereby showing the most impact. From the philosophical, pragmatic perspective framing this article, the video with the most comments was thus seen as the most useful by viewers and, consequently, for our analysis [162–164]. Qualitative research aims to achieve saturation [165] and, since analyzing comments is shorter compared to other qualitative methods, such as analyzing interviews, an attempt was made to use the largest possible database. Based on one video, saturation could already be achieved, which is why adding another video would not have led to any further insights. The saturation is also reflected in the comparability of the results with those of similar research [91]. We therefore selected a video from the Live Storms Media channel entitled "8-31-2021 Grand Isle, La Hurricane Ida aftermath—widespread destruction drone" [166]. The video was uploaded on 1 September 2021 and has since received 845 comments (as of 2 February 2023). The video shows a drone flight of Grand Isle after Hurricane Ida that reveals the damage after the event, such as destroyed buildings, damaged infrastructure, and damage to other property and objects such as means of transportation. Parts of the island are still flooded at the time of filming and debris and rubble are scattered across the island.

The comments were then subjected to an inductive, content-structuring qualitative content analysis according to Kuckartz and Rädiker [150]. The analysis was carried out using MaxQDA 2020 software. Content-structuring qualitative content analysis is particularly suitable for exploring media constructions as the focus is on the content aspects that are to be identified and structured [167]. The procedure is divided into seven phases by Kuckartz and Rädiker [150].

The first phase is described by Kuckartz and Rädiker ([150], translated by the authors) as "initiating text work, memos, case summaries", in which initial ideas for categories are drawn up. In the second phase, the first main categories are developed, based on the categories of the first phase. In this phase, a codebook was already created. The main categories had a high level of abstraction and referred to the argumentation patterns and intentions of the persons commenting. The category "not part of the analysis" was introduced, which contained comments that were not suitable for analysis for various reasons. This included, for example, duplicate, incomprehensible, and non-English comments. A first test run with the main categories was carried out and led into phase 3, i.e., the first coding process. The main categories were assigned to the respective comments, whereby a comment was understood as a coding unit in order to enable a frequency analysis of the categories. In phase 4, subcategories were inductively formed. The subcategories were based on a lower level of abstraction than the main categories. This was followed by a second coding process in phase 5, in which the comments were assigned to the subcategories.

Once the comments had been fully coded, the codebook could be finalized. The codebook was then used to categorize the data in its entirety in a final coding process. In the case of comments that could not be clearly assigned to one code, the dominant statement was selected. With the category system and coding, secondary evaluation steps could then be carried out in phase 6 [150] (p. 147). For this purpose, a comparison of the main and subcategories and the formation of interpretative patterns was carried out. The results of the code frequencies were also quantified and visualized. In the last phase, the results were written down and the procedure was documented.

6.2. Guided Interviews and Ero-Epic Conversations to Analyze the Individual Experience

To analyze the individual experience of coastal land loss in Louisiana, we conducted a total of 27 guided interviews and 30 ero-epic interviews with a total of 71 people living in the coastal region of Louisiana between May and October 2022. Girtler [168] characterizes ero-epic interviews as a form of interview that arises from chance encounters in everyday life and follows a topic-centered but open and unstructured form, thus creating a low-threshold environment for interviewees. The open structure of the interviews allows the interviewees to speak freely and present their points of view [169,170]. As we wanted to shed more light on the constructs of land loss, this method was more suitable compared to structured interviews. The main interview locations were lingering places with a relaxed atmosphere, such as cafés, lively squares (for example, on university campuses), or tourist attractions, where we approached specific people and asked them for an interview or struck up a conversation through chance encounters and spontaneous interactions. The interviews lasted from a few minutes to over an hour, with up to four interviewees taking part. All interviewees had in common that they lived in southern Louisiana; no further restrictions were made regarding age, ethnicity, gender, or socio-economic status as the focus of the study was on the individual experience and personal perception of diverse individuals—not on a group that was as homogeneous as possible. In total, we conducted interviews at 13 different locations in the coastal region of Louisiana. Figure 2 shows the locations where interviews were conducted, with the point size of the locations increasing linearly with the number of interviews conducted at that location. Among the interviewees, there was little physical distance between their homes and the Louisiana wetlands and areas affected by coastal land loss. Nevertheless, the different distances to the coastline and wetlands reveal possible differences in the interviewees' perceptions.

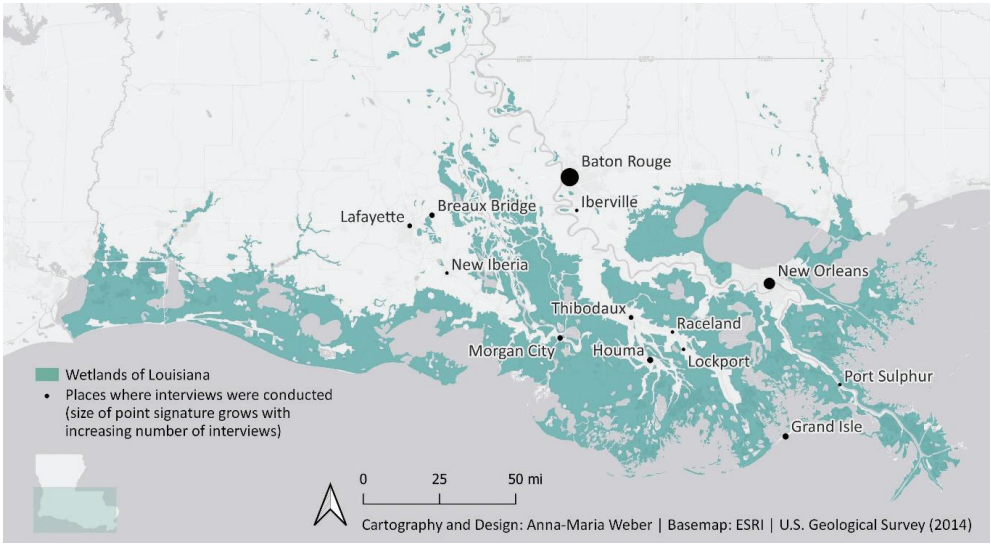


Figure 2. The map shows the locations where the guided interviews and ero-epic interviews were conducted. All locations were within the coastal region of Louisiana and close to the wetlands (own representation based on [171,172]).

The questions used to stimulate the ero-epic interviews were based on the questions used in the guided interviews, which made it possible to create a level of comparison between the interviews. The questions related to individual perception, personal experience, and the assessment of one's own impact and resulting measures were aimed at working out different patterns of interpretation and evaluation. For this purpose, the collected material was subjected to inductive coding after the interviews were conducted and evaluated in the sense of a summarizing content analysis according to Mayring's scheme, as this enables the systematic investigation of qualitative content with regard to different interpretations and attributions [149,170,173,174]. However, the interviewees were only a small, selective subset of the diverse coastal population of Louisiana. Baton Rouge and New Orleans are overrepresented in the data corpus due to the fact that these are the two most populous places and provided busy areas in which to conduct the interviews. In addition, many of the people and groups of people we approached, especially groups with less symbolic capital, such as ethnic minorities or the socio-economically disadvantaged, refused to be interviewed, revealing a lack of trust in strangers on the one hand and research fatigue on the other. Lambert et al. [175] (p. 12) had a similar experience with their interviewees in their study, which they attributed to the "repeated experience of turning one's personal experiences into an object of study for outsiders".

7. The Media Construction of Coastal Land Loss in Louisiana

The results of the analysis of the YouTube comments are presented below. (Comments have been grammatically adjusted and spell-checked to improve readability. Emojis have been removed and comments anonymized.) The comments are numbered consecutively; responses to comments are displayed with a hyphen (e.g., the sixth response to the 200th comment is referred to as K200-6). In total, the 715 comments were divided into four categories (cf. Figure 3).

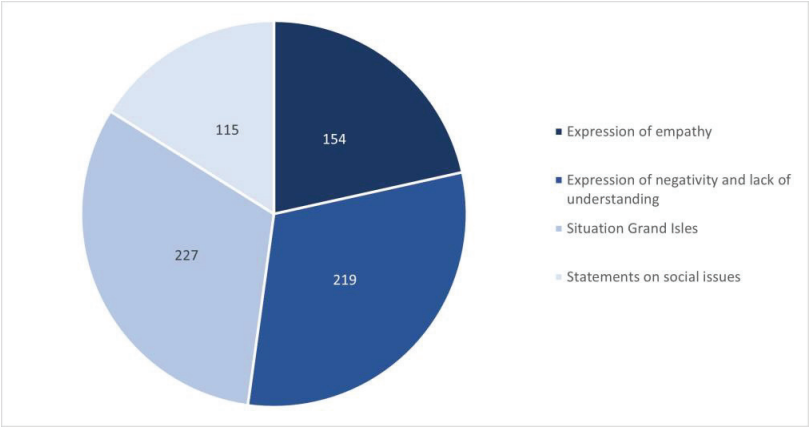


Figure 3. Main categories of the analysis of media construction via YouTube comments (own illustration).

7.1. The Situation on Grand Isle

The first pattern of interpretation consisted of descriptive explanations as well as personal opinions on the situation of Grand Isle. However, the comments were mainly about how the physical environment of Grand Isle is perceived.

These included factual statements about Grand Isle in general. For example, there were statements about Grand Isle without any reference to the hurricane event (K042-6) or statements that only referred to facts about hurricanes, without reference to Grand Isle (e.g., K025-1). The future of Grand Isle and hurricanes was also considered in this context (K266). The event itself and its visible consequences were also discussed. On the one hand, there were the physical consequences, such as descriptive comments about the destruction (K037), and on the other hand, socio-economic consequences were explained (K004-07). Comparisons were also frequently made, especially of the destruction and damage caused by other, similar events (K168), which led to the evaluation and classification of the event, e.g., that the damage caused by Hurricane Ida was worse than that of another event and what significance this would have for the duration of the reconstruction (K195). It was also discussed whether an evacuation had taken place (K002). A frequently discussed aspect was the construction, which was discussed in terms of buildings and structures and their quality and functionality, especially in view of the hurricane exposure (K078). The degree and differences of destruction between the buildings were frequently discussed (K077) and suggestions were made for better, more functional construction methods and better coverage of the legal building codes (K093-6). The effectiveness of hurricane protection measures was also discussed and questioned (K004-06).

7.2. Statements on Social Issues

Another pattern of interpretation was that the commenters made statements about social issues that also contained opinions. While some of these statements were clearly associated with Grand Isle, others often only tangentially touched on the subject of Grand Isle and Hurricane Ida and expressed general views evoked by the event. These commenters' statements were often about assigning responsibility for the event.

Responsibility was sought in religion or higher forces, for example, when God was assigned responsibility for Hurricane Ida (K296). At the same time, there were also expressions of criticism of religious practices as a counter-reaction to people praying for the people on Grand Isle (K026-2; cf. Expression of empathy). "Mother Nature" was identified as a higher force that was also seen as responsible for the event (K121). What is striking here is the reference to the inequality of power between a higher force or a religious leader and man-made things. Another aspect was the climate, with a particular focus on climate change and its significance for Grand Isle (K366). As a result, criticism was also leveled

at the handling of climate change (K210-08). This was contrasted with conspiracy theory approaches, such as the conspiracy theory surrounding H.A.A.R.P., to which responsibility for the event was also conferred (K298). Responsibility was also given to politics or the government, which was accused of not paying sufficient attention to the pursuit of climate protection goals (e.g., K459). The government's handling of the existing situation was criticized (K220) but also met with approval (K039-05). The way insurance companies deal with situations like Hurricane Ida was also criticized in, for example, explanations of how difficult it is to insure houses in hurricane areas (K035-2). In addition to these more frequently mentioned aspects, there were a few others in which the commenters discussed other subjects, such as aid organizations (K039-03).

7.3. Expression of Empathy

In the following two sections, it can be seen that the commenters referred strongly to the people of Grand Isle and how they dealt with the situation. The comments analyzed included reactions from the commenters, which showed in various ways that they had empathy for the people of Grand Isle. This can be seen both in an understanding of how the population was being treated and in the emotions expressed by the commenters on the situation of the population.

One aspect that showed the empathy of the commenters was expressed in the acceptance of reconstruction after the event by, for example, hoping that reconstruction could take place (K291). Arguments were also given to justify reconstruction (K027-05). For some commenters, the video triggered personal memories, which was why they shared their inner view of Grand Isle in the comments. These included both positive memories, for example, when a person talked about their former life on Grand Isle (K339), and negative connotations, for example, when someone was disappointed to discover that their uncle's summer house was now gone (K489). Empathy also became clear when people stated that they were in a similar situation. Some people expressed that they lived in the area around Grand Isle, where Hurricane Ida also caused damage (K503). Another aspect was the commenters' understanding of the housing decisions of the residents. For example, the connection to home was mentioned: "Clearly, there's more to a home's value than meets the eye" (K184). One argued that hurricanes do not occur very often and, therefore, there is no need to constantly rebuild (K097-1). Further reasons for understanding the decision to live there were proximity to the workplace (K042-3) and the beauty and way of life on the island (K281). Empathy was also expressed through concern; hope or joy that the population had been evacuated and was safe was mentioned several times (e.g., K037-1). There were also comments without an argumentative structure in which it was expressed, for example, that the commenters think of the video or the event as sad (e.g., K009, among many) or heartbreaking (e.g., K259, among others). The commenters were sorry (K359) or felt bad (K144). Wishes and hopes were expressed (K374) and prayers were voiced for those affected (e.g., K507). They also responded to negative comments and defended the residents or those affected (K024-1).

7.4. Expression of Negativity and Lack of Understanding

Furthermore, the people commenting also referred to the population of Grand Isle, but expressed themselves negatively towards them or had a lack of understanding of the way the population of Grand Isle was dealing with the situation. In some cases, the commenters even went further and became insulting or sarcastic.

One aspect of this was the attribution of blame. The population of Grand Isle was blamed for personal, social, and worldly disadvantages. For example, financial disadvantages were cited, such as the increase in insurance resulting from the event (K186) or the redistribution of tax payments to the population of Grand Isle (K116-01). Another motive for apportioning blame was environmental pollution and waste of resources (K456). It was also argued that the population was not affected because it was wealthy (K428) and therefore not confronted with substantial damage from Hurricane Ida (KK039-09). This

was also related to the assumption that a large proportion of the buildings were used as vacation homes from which a profit was made, especially if the insurance covered the damage (K035-1). Similar comments implied that there was no population on Grand Isle and, therefore, nobody that could be affected (K028-1). In contrast to the previous section, there was also resistance to the reconstruction. For example, it was commented that the residents should relocate (K172). The arguments that hurricanes would return and become more frequent and that it is a cycle of reconstruction and destruction in which the population finds itself (K058-3) were often given as reasons for rejecting reconstruction. This contradicted one of the comments from the previous section, in which it was claimed that hurricanes are rare (K027-5), making it clear that the knowledge of the commenters differs. The population was also described as crazy (K119-1) and insulted (e.g., K027-10) due to reconstruction efforts. Other possible uses for the island were also discussed and suggestions were made as to how reconstruction could be made possible (e.g., K349). There was a great lack of understanding as to why people expose themselves to a situation like Hurricane Ida (K389). The lack of understanding was often expressed by referring the situation to themselves and stating that they would not want to expose themselves to the situation (K163). It was also argued that the situation was to be expected (e.g., K438). Here, too, attachment to the homeland and the beauty of the island were cited, but the risks were rated as more significant (K166). Jokes were also made at the expense of those affected and irony or sarcasm was expressed (e.g., K433), which was also an expression of negativity and a lack of understanding.

8. The Extra-Media Construction and Individual Experience of Coastal Land Loss

Following the evaluation of the YouTube comments, the following section contrasts the findings of the guideline-based interviews and empirical discussions with regard to the individual experience of coastal land loss in Louisiana. The aim is to supplement and compare the results from the social media analysis with the internal perspective of people living and affected there. The section is structured according to the thematic aspects that emerged from the empirical material and supplemented with direct quotes from the interviews. The quotes are marked with an abbreviation (I = guided interview, E = ero-epic interview, numbered chronologically), which enables a clear allocation and differentiation of the various positions of the interviewees. First, the interviewees' attachment to the place and their knowledge of and points of contact with coastal land loss are discussed. This is followed by comments on the personal experiences and events described and the measures taken in relation to the ongoing loss of land. A more in-depth and detailed presentation of the results, limited here to the essential aspects, can be found in Weber [176].

8.1. The Attachment to Southern Louisiana as Home

All interviewees exhibited an a-modal attachment to the coastal region of Louisiana and their hometown, constructed through personal references and experiences. The interviewees particularly emphasized the diverse culture, music, typical regional cuisine, and "colorful, vibrant" (I04) life. In addition, the interviews show that attachment to place was primarily based on strong family and intergenerational ties as well as deeply rooted history and communities. The interviewees outside Baton Rouge and New Orleans also had a close connection to the wetlands. Swamps, bayous, marshes, cypresses, and alligators were not emphasized as a threat but as part of their living environment and were seen as a landscape element that defined their home. This was particularly evident in the high value placed on outdoor activities such as hunting, fishing, and other water-related activities, which respondents accentuated as typical leisure activities. It was also emphasized that the wetlands and waterways of Louisiana formed the livelihood and economic basis for fishermen, oyster farmers, tourist sport fishermen, and the oil and gas industry in Louisiana.

8.2. Knowledge about and Points of Contact with Coastal Land Loss

Although a strong connection to the coastal region of Louisiana was clear among all interviewees, the question of what associations the interviewees had with land loss and whether they could name the processes of land loss showed that there were very different points of contact and levels of knowledge about land loss. Eight of the interviewees, all of whom lived in Baton Rouge or New Orleans, stated that they had heard nothing or not much about coastal land loss: "No, I don't know anything about it [land loss] actually." (I10). The knowledge and points of contact of most interviewees, spread across all interview locations, were superficial, lacking in detail, and b-modally constructed, often limited to the statement that the coast was disappearing into the sea: "I think we're losing our coast. [...] The water keeps washing away our coast. [...] And that's what we're fighting with right now. Saving our coast." (E26). However, some of the interviewees stated that land loss was a very present topic for them that they were frequently confronted with as they had a professional connection (c-modal landscape interpretation) or personal experience with it (a-modal landscape interpretation).

When asked whether they could name the reasons for the loss of land, most respondents stated that they were not sure. In this context, the interviewees attached great importance to c-modal special knowledge, which was reflected in the fact that many of the interviewees referred to experts and classified themselves as uninformed and incompetent: "You'd have to ask a professional" (I18). The assumptions made by the interviewees were correct in all cases, even if they were superficial and incomplete, and covered a broad spectrum of the natural and anthropogenic processes investigated. The greatest discrepancies in the assessment and interpretation of the processes taking place were evident in relation to the effects of climate change and the oil and gas industry. While one interviewee believed that land loss "has something to do with climate change as well as continue hurricanes basically eroding" (I16), another interviewee denied man-made climate change and emphasized that he was "not a big believer in the effects of man's effects on global climate change" and did not believe "that has anything to do with" (I21). The influence of the oil and gas industry was also assessed ambivalently, depending on the prioritization of ecological or monetary aspects (see in more detail, [177]).

It is also clear from the interviewees' statements that for the majority of respondents, land loss was not a topic that was talked about much in everyday life. It becomes particularly apparent from the interviewees from New Orleans and Baton Rouge that "there are so many other things that are going on in life" (I22) and immediate problems such as crime tend to be part of daily conversations with family, friends, and acquaintances. This was different for respondents who reported their own experiences and personal experiences or the stories of family, friends, or other people close to them. Land loss played a role in everyday life, especially for those sections of the population who lived on fishing, enjoyed fishing or hunting privately, or had a property on the water as they were in the areas affected by land loss on a daily basis and able to perceive and experience the landscape changes through constant confrontation. One interviewee stated, "You can ask a five-year-old child about the vanishing coastline, and they'll say: 'We know about it and this is what's happening. And my daddy can't make as much money on the shrimping industry'" (E12).

8.3. Personal Experiences and Perceptions of Landscape Change

The differences in knowledge of and points of contact with land loss outlined in the previous section resulted in different assessments of how affected the respondents themselves were. More than half of the respondents did not see coastal erosion as a threat to their own homes and livelihoods. On the one hand, these respondents had very little knowledge about land loss or expressed mistrust that the land loss processes really (will) take place on such a scale and, on the other hand, some of them felt too far away from the vanishing coastline in terms of time and space.

Even if the majority of respondents did not consider themselves to be affected by land loss, many still recognized a threat to other parts of the population, communities, and

individuals in Louisiana: "I would say it doesn't play a role in our daily lives but certainly in the lives of those people that have settled on the coast, who make their living from fishing and going offshore, supporting the oil and gas industry. We've watched the Gulf of Mexico get closer to the city each and every year" (I18). Some interviewees cited the aforementioned Grand Isle as a prominent example of visible land loss and communities threatened by coastal erosion. Other interviewees also recognized a threat to their own homes and livelihoods, although they mainly referred to the directly noticeable consequences of extreme weather events, such as storm damage to their own homes or infrastructure and flooding, and only rarely mentioned the long-term changes to the landscape, such as the loss of their own land and vegetation damage due to saltwater intrusion.

The interviews conducted also show that the assessment of one's own impact was strongly dependent on landscape 1a, the respondents' own experiences with environmental change. Some of the interviewees reported that they themselves or family or acquaintances had witnessed changes to wetlands and coastal communities that they attributed to coastal land loss. The interviewees talked about their favorite fishing spots that no longer exist, disappeared landmarks on the water, marshland that had turned into open sea, and trees that had died due to saltwater intrusion, reflecting the poor state of the ecosystem. However, the interviewees also emphasized that these changes were only noticeable to those who had lived in the coastal region for decades, if not generations, implying that, in their view, awareness could only develop with time and experience. In addition, these interviewees showed that the physical changes also influenced their own identity and emotional attachment to their homeland. For them, part of their "livelihoods" (I02), "heritage" (I18), "tradition" (E12), family history, and memories disappeared along with the land. Accordingly, the loss of land also had a strong emotional impact on the locals of the coastal region, but only for those whose individual experience was characterized by personal, a-modal experiences.

Despite the emotional strain, or precisely because of the close emotional ties, leaving home and moving away voluntarily was not an option for any of the interviewees. The deeply rooted family structures and communities were a decisive argument for the interviewees to maintain their living environment. In addition, in some cases, economic factors forced the coastal population to stay as moving was associated with high costs, and their lifestyle and professional qualifications were adapted to the marsh areas. One interviewee explained, "I have a best friend who is a fisherman and shrimper, and you couldn't move him somewhere else. He doesn't have another skill. So he has to stay here. And so that's why we don't move. And besides, all our family is here. We ain't going nowhere" (E12). Another argumentation pattern of the interviewees was the normalization of their own vulnerability. The potential risk of erosion and extreme weather events are seen by many as "part of life" (E09) and as predictable events with sufficient preparation time, which is a clear advantage in contrast to other natural hazards such as earthquakes. Nevertheless, at the same time, other interviewees from New Orleans and Baton Rouge expressed a lack of understanding as to why coastal residents do not move away despite repeated destruction from hurricanes and progressive erosion. In doing so, these interviewees ignored the close emotional and identity-forming ties to their hometown and devalued the a-modally constructed relationship to the coastal region through their b-modal construction.

8.4. Measures to Save the Coastal Region and Strategies for Action

Land loss was consistently viewed as negative by the interviewees, and a majority of respondents expressed a desire to do something about it, although responsibilities were allocated differently and the measures and action strategies for protecting and restoring wetlands were prioritized and evaluated very differently. Some placed great expectations on scientists and engineers (c-mode) in the hope that they would stop coastal erosion by building better and higher dykes or artificially installed grass banks to trap sediment. More often, however, politicians were seen as responsible for the protection and restoration of wetlands and the corresponding measures. However, there was also criticism that political

actors were shirking responsibility, not using or wasting funds, and not working on long-term goals and projects. The mistrust of political actors was reinforced by the accusation that politicians work too closely with the oil and gas industry and place economic interests above ecological ones: "Louisiana is very invested in oil and gas. I feel like that's not so much of a concern for that industry, the preservation of wetlands. So they have maybe a little too much sway in the government" (I16). Accordingly, the oil and gas industry was also accused of not caring about protecting the landscape and disregarding environmental protection regulations.

Those surveyed also stated that they took the initiative themselves. For example, to secure their own land and private property, they installed erosion protection materials or rock fills or planted special grasses. In addition, some of the interviewees reported that they had helped with community activities (often in a school context), such as planting trees and grasses or collecting garbage along the bayous, or that they had often heard about them. The collection of Christmas trees, which act as sediment traps in areas particularly affected by erosion, was also frequently mentioned. Even if the effect of the community projects was small, as some of the interviewees noted, it was clear from the interviews that they were very important for raising awareness, educating the population, and creating a sense of community.

Although the respondents pointed to a wide range of measures to protect and restore the coast, only a few believed that erosion could be prevented by these measures. The majority saw themselves as exposed to land loss and were of the opinion that the measures taken so far had not had the desired effect, politicians were not sufficiently interested in the issue, and time was running out. For many respondents, this created a feeling of inevitability and inability to act, which resulted in a pessimistic basic attitude: "God, I have no hope that we'll ever fix [it]. [...] I really don't think we're going to fix these problems. I think it's just going to keep getting worse and worse" (I13).

9. Reflexion of Empirical Findings and Discussion

Against the background of the theoretical foundation of this article, especially through the neopragmatic meta-theoretical framing and the corresponding theory and method triangulation, the diversity of interpretations of coastal land loss in southern Louisiana becomes particularly clear. The comments and interviews analyzed reveal differences in the construction and interpretation of coastal land loss, particularly with regard to the reference to landscape theory and the source of information. The various subsystems according to Luhmann [45,46] are brought into resonance by landscape processes and reveal different perspectives on them. The economic system is affected by, for example, the loss of marshland covering pipelines of the oil and gas industry as well as insurance covering hurricane damages. The political subsystem on the other hand is utilizing coastal land loss in election campaigns, while the legal subsystem is, among other things, establishing building codes in the coastal area. The mass media system also influences the construction of reality and leads to different opinions regarding the current challenges on the Louisiana coast. The diverse constructions of reality correspond to individual combinations of one's own experience in the a-mode and the interpretations and world views conveyed by the media and society in the b-mode (cf. [55–57]). These become particularly clear depending on whether there is a personal experience of the effects of the loss of the coast and the passage of hurricanes because the constructions can be differentiated into internal and external views of the topic. As Burley [178] and Lambert et al. [175] also found in their studies, the part of the coastal population that has a personal connection to the wetlands and feels affected by the loss of land has an a-modal constructed internal view based on first-person experiences of the issue (cf. [55–57]). Lambert concluded that "familiarity with and knowledge about coastal land loss was most often related to either indirect experiences through social connections or direct, personal experience" [175] (p. 7). Burley also pointed out that the affected people have a physical closeness as well as a "cognitive closeness" to land loss [178] (p. 106). While the studies by Burley [178] and Lambert et al. [175] primarily

interviewed people with an internal view, the triangulation of methods and data in this study also allowed the external view to be included to investigate possible differences in the construction of coastal land loss. The empirical findings show that those who have had no personal contact with the effects of coastal land loss and who have not yet experienced a hurricane base their interpretations of it on socially and media-communicated content of the b-mode (cf. [55–57]). The integration of knowledge in the c-mode is only occasionally evident, particularly in the media discussion (cf. [55–57]).

While the construction of coastal land loss in Louisiana was largely shaped by the interviewees' personal experiences from an internal perspective—which was not least due to the close proximity of the interview locations to the examined space 1, the Louisiana coast—it becomes evident in some of the comments in the analyzed media discussion that there were no personal experiences. However, despite the strong connection of the interviewees and some of the commenters to the coastal region and their personal experiences, there were still differing views. In particular, the question of whether it was permissible to settle so close to the coast and whether destroyed houses should be rebuilt or not were the subjects of heated debate. From an internal perspective, there was often understanding and, due to similar interpretations in the a-mode, great sympathy for those affected—especially as some of the residents of South Louisiana who were not yet directly affected were aware that they too would most likely be more severely affected by the effects of coastal land loss in a few decades' time. A lack of understanding and clear statements against the reconstruction of the external view were sometimes expressed in morally condemning and sometimes even personally offensive statements (cf. also [113]). It is noticeable here that interviewees living in urban regions in particular and—as far as can be seen in the comments—commenters considered themselves less vulnerable than directly affected coastal residents of the marshes and Barrier Islands due to the assumed safety of urban infrastructure and the sometimes greater geographical distance. It is also evident that the loss or uninhabitableness of a property (Landscape 1) in particular, as a direct consequence of coastal land loss, represented a loss of economic capital for those affected and in, some cases, posed extreme challenges with regard to resettlement, sometimes even making it impossible and thus adding to the emotional burden of the loss of the home (landscape 1a) (cf. [175,178]). More so, the only options for protection were investing in higher building standards, especially rising buildings high above the ground or other adaptions to homes, as well as insurance covering hurricane damages. Both options require the investment of economic capital (in the sense of Bourdieu [48]), with the latter having extremely high insurance rates and, as past hurricane events have shown [179,180], the risk of insurance companies not being able to reimburse policyholders due to bankruptcy in the immediate aftermath of hurricanes. Adapted ways of building and knowledge of the best ways of protecting homes as well as the soil and other physical objects from being swept away by floods and rising sea levels also indicate a high resilience of affected people, thus referring to a high social capital in the sense of Bourdieu [47]. In this context, the interviewees referred in particular to social integration and local social cohesion, with affected people helping each other if needed. Interestingly, though, while the interviewees referred to the high social cohesion of the locals, many of the social media comments showed solidarity with those affected; yet, others—often morally charged and derogatory accusations with a lack of empathy—indicated that social cohesion was higher on a local level than on the national or even international levels. Regarding cultural capital in the sense of Bourdieu [47], the interviewees emphasized the importance of the proximity of the coastal inhabitant to the Gulf of Mexico as crabbing, fishing, and oyster farming, among others, not only represent the economic basis of life for many but also form an important part of the local culture. Subsequently moving away from their coastal communities would result in the loss of cultural and social capital as well as economic capital, as the monetary value of coastal land is decreasing.

Furthermore, only very few interviewees and commenters made a connection between increased coastal erosion and anthropogenic climate change; the conclusion that more

sustainable lifestyles and a more sustainable approach to the environment could also help to mitigate the effects of climate change was not drawn. Instead, the reasons for the loss of coastal land were often sought in 'Mother Nature', God, or even the people affected themselves (as they could have moved somewhere else, according to some statements).

These empirical findings stated above show the importance of the theory and data triangulation of the meta-theoretical basis of neopragmatism used in this article because without a combination of different data corpora from personal conversations and media discussions, these differences between the internal and external views regarding the construction of coastal erosion could not have been detected to this extent, and only in this way could the complexity of the facts be analyzed and presented. The results of the qualitative analysis of the media discussion in the comment column of the YouTube video on the effects of Hurricane Ida (2021) on Grand Isle also show parallels with a similar study with regard to the categories identified [113], which also analyzed the media discussion of a comment column below another YouTube video on the effects of Hurricane Ida on Grand Isle. Here, too, there were differences in the construction of coastal land loss by those affected and those not affected, which erupted in a partly morally charged discussion about who was to blame for the destruction on Grand Isle (see in more detail [113]). As the analyses were carried out independently of each other and with two different databases, the results of the two studies reinforce each other and are, therefore, even more valid and representative. The frequent mention of Grand Isle by the interviewees as being particularly affected by coastal land loss also confirms the choice of YouTube videos dealing with Grand Isle and their comments.

The results of the present study confirm those of similar studies in which (media) discussions about changes in landscape 1 and their implications are morally charged and become identity and value conflicts (see, e.g., [42,55,91,113,181]). Referring to the productive potential of conflicts according to Dahrendorf (c.f. [49–51]), there are not just two but many parties to the conflict, with not just one but many different, yet connected aspects at the center of the conflicts, resulting in highly complex relations and structures. All of the conflicts were characterized by a mutual lack of understanding between several parties to the conflict—between those affected who did not want to leave their homes and those not affected who demanded resettlement and assumed that nobody wanted to live in the eroded landscape 1 of the coast and between those who saw coastal erosion as a threat and those who did not. Others considered protective measures and 'saving' the coast to be important but were opposed to the state or the oil and gas industry, which, in their opinion, did not take enough or even any counteractive measures. The legitimacy of the needs and views of the opposing party was usually not recognized; yet, according to Dahrendorf (c.f. [50]), parties have to recognize the legitimacy of the positions of the others to be able to settle the conflict productively. Moreover, there was no intervening party, to which Dahrendorf (c.f. [50]) ascribes great potential of settling conflicts productively, as the state—which is usually attributed to this position according to Dahrendorf [50] (p. 44)—is partially involved in the conflict itself. This raises the question of whether these are actually productive conflicts in Dahrendorf's sense or if the conflicts require stronger regulation.

10. Conclusions—Morally Charged Internal and External Views

The aim of this article was a fourfold one. First, on the level of the research object, we identified different patterns of categorization, evaluation, and interpretation of landscape processes and their relations in the context of coastal land loss in Louisiana, USA. Secondly, on the level of landscape-theoretical research, we aimed to understand the different landscape-related constructions, especially regarding individual experiences and social constructions of landscape. The third aim of this article was on a meta-theoretical level, testing the suitability of the applied triangulation of theories, methods, data, etc., of the neopragmatic approach. Finally, we contributed to the understanding of perception interpretation and the evaluation of landscape processes that are partly caused by climate change in this coastal land loss in Louisiana.

The empirical findings of this article have once more confirmed that coastal land loss in Louisiana remains a highly complex and interconnected issue that is constructed and interpreted in very diverse ways by people affected as well as others. The theoretical foundations and empirical results presented in the previous sections give rise to a diverse and complex field of research that can be broadly considered using the neopragmatic approach. The empirical investigations of qualitative interviews and media discussions reveal very different interpretations and constructions of coastal land loss in Louisiana, which led to morally charged discussions about the reasons for and effects of coastal erosion. Depending on the personal experience of the effects of coastal land loss, internal and external views clash, which are not least strongly influenced by the media. With regard to the initial objectives of this article, patterns of interpretation, categorization, and evaluation of the landscape processes on the Louisiana coast could be identified at the level of the research object, and their interrelationships were examined, which were described in detail in Sections 7 and 8. At the level of landscape theory research, the differentiation of landscape-related constructions could be considered and analyzed through various theoretical frameworks:

1. The internal and external perspectives were relevant to the perception of transformation processes and had an impact on the understanding of other people's decisions.
2. There were various lines of conflict between different conflict partners and parties, which had hardly any productive potential in the sense of Dahrendorf [49–51] due to the lack of regulation.
3. The various subsystems according to Luhmann [45,46] were brought into resonance by landscape processes and revealed different perspectives on them. The mass media system also influenced the construction of reality and led to different opinions regarding the current challenges on the Louisiana coast.
4. Economic capital according to Bourdieu [47,48] was particularly relevant in the discussion about coastal land loss processes. Existing economic deficits impacted those affected and the land loss processes also led to economic differences. Social capital, especially social structures in the aftermath of hurricanes, was emphasized, as well as cultural capital.
5. The loss of coastline in Louisiana was constructed in the context of all three landscapes and in all three modes, thus revealing different perspectives.

Finally, on a meta-theoretical level, it can also be stated that the combination of methods, theories, researchers, etc., in accordance with the neopragmatic meta-theoretical framework can achieve advantages in researching complex issues. Framing questions through individual theoretical or methodological approaches cannot do sufficient justice to complex relationships, facts, and constructions. Overall, this article was able to test the suitability of a further neopragmatic combination of theories. In conclusion, it should be noted that sustainable lifestyles and actions were hardly addressed in the media discussion and interviews conducted, although sustainable action in the coastal region can have positive social, economic, and, in particular, ecological effects, including in regard to coastal protection and the sustainability of mitigation strategies and protective measures. However, it remains to be seen to what extent the areas already affected by erosion can be 'saved'.

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References

1. Barras, J.; Beville, S.; Britsch, D.; Hartley, S.; Hawes, S.; Johnston, J.; Kemp, P.; Kinler, Q.; Martucci, A.; Porthouse, J.; et al. Historical and Projected Coastal Louisiana Land Changes: 1978–2050: USGS Open-File Report. OFR 03-334 (Revised January 2004). Available online: https://pubs.er.usgs.gov/publication/ofr03334 (accessed on 2 December 2021).
2. Couvillion, B.R.; Beck, H.; Schoolmaster, D.; Fischer, M. Land area change in coastal Louisiana (1932 to 2016). Available online: https://pubs.usgs.gov/sim/3381/sim3381_pamphlet.pdf (accessed on 24 January 2020).
3. Maldonado, J.K. Everyday practices and symbolic forms of resistance: Adapting to environmental change in coastal Louisiana. In *Hazards, Risks, and Disasters in Society*; Collins, A.E., Ed.; Elsevier: Amsterdam, The Netherlands; Kidlington, UK; Waltham, MA, USA, 2015; pp. 199–216, ISBN 9780123964748.
4. Muir, R. On Change in the Landscape. *Landsc. Res.* **2003**, *28*, 383–403. [CrossRef]
5. Duttmann, R.; Kühne, O.; Weber, F. Landschaft als Prozess—Eine Einführung. In *Landschaft als Prozess*; Duttmann, R., Kühne, O., Weber, F., Eds.; Springer VS: Wiesbaden, Germany, 2020; pp. 3–13.
6. Mead, G.H. Social psychology as counterpart to physiological psychology. *Psychol. Bull.* **1909**, *6*, 401–408. [CrossRef]
7. Mead, G.H. Social consciousness and the consciousness of meaning. *Psychol. Bull.* **1910**, *7*, 397–405. [CrossRef]
8. Chilla, T.; Kühne, O.; Weber, F.; Weber, F. "Neopragmatische" Argumente zur Vereinbarkeit von konzeptioneller Diskussion und Praxis der Regionalentwicklung. In *Bausteine der Regionalentwicklung*; Kühne, O., Weber, F., Eds.; Springer VS: Wiesbaden, Germany, 2015; pp. 13–24, ISBN 978-3-658-02881-7.
9. Kühne, O. Foodscapes—A Neopragmatic Redescription. *Berichte Geogr. Landeskd.* **2023**, *96*, 5–25. [CrossRef]
10. Kühne, O.; Jenal, C. Baton Rouge (Louisiana): On the Importance of Thematic Cartography for 'Neopragmatic Horizontal Geography'. *KN–J. Cartogr. Geogr. Inf.* **2020**, *71*, 23–31. [CrossRef]
11. Rorty, R. *Consequences of Pragmatism: Essays: 1972–1980*; University of Minnesota Press: Minneapolis, MN, USA, 1982; ISBN 0816610649.
12. Rorty, R. *Objectivity, Relativism, and Truth*; Cambridge University Press: Cambridge, UK, 1991; ISBN 0521353696.
13. Rorty, R. *Contingency, Irony, and Solidarity*; Reprint; Cambridge University Press: Cambridge, UK, 1997; ISBN 9780521353816.
14. Rorty, R. The Contingency of Language. In *Rhetoric in an Antifoundational World: Language, Culture, and Pedagogy*; Bernard-Donals, M.F., Glejzer, R.R., Eds.; Yale University Press: New Haven, CT, USA, 1998; pp. 65–85.
15. Rorty, R. *Essays on Heidegger and Others*; Cambridge University Press: Cambridge, UK, 1991; ISBN 9780511609039.
16. Rorty, R. *Philosophy and Social Hope*; 1. publ; Penguin Books: London, UK, 1999; ISBN 0140262881.
17. Putnam, H. *Pragmatism: An Open Question*; Blackwell Publishers: Oxford, UK, 1995.
18. Putnam, H. *Renewing Philosophy*; Harvard University Press: Cambridge, MA, USA; London, UK, 1992.
19. Putnam, H. Why There Isn't a Ready-made World. In *Contemporary Materialism: A Reader*; Moser, P.K., Trout, J.D., Eds.; Routledge: London, UK, 1995; pp. 233–253.
20. Reese-Schäfer, W. *Richard Rorty zur Einführung*; Junius Verlag: Hamburg, Germany, 2016.
21. Müller, M. *Rorty Lesen*; Springer VS: Wiesbaden, Germany, 2021.
22. Gustafsson, M.; Brandom, R.B. Rorty and His Critics. *Philos. Rev.* **2001**, *110*, 645. [CrossRef]
23. Mounce, H.O. *The Two Pragmatisms: From Peirce to Rorty*; Routledge: London, UK; New York, NY, USA, 2002; ISBN 9780203045213.
24. Menand, L. *The Metaphysical Club: A Story of Ideas in America*, 1st ed.; Farrar Straus and Giroux: New York, NY, USA, 2001; ISBN 0374528497.
25. Barnes, T.J. American pragmatism: Towards a geographical introduction. *Geoforum* **2008**, *39*, 1542–1554. [CrossRef]
26. James, W. *Pragmatism: An Old Way for Some New Ways of Thinking*; Longmans, Green and Co.: New York, NY, USA, 1907.
27. Gloy, K. *Wahrheitstheorien: Eine Einführung*; Francke: Tübingen, Germany, 2004; ISBN 3772030106.
28. Dewey, J. *Logik: Die Theorie der Forschung*; 2. Auflage; Suhrkamp: Frankfurt, Germany, 2016; ISBN 9783518295021.
29. Neubert, S. Pragmatismus—Thematische Vielfalt in Deweys Philosophie und in ihrer heutigen Rezeption. In *John Dewey: Zwischen Pragmatismus und Konstruktivismus*; Hickman, L.A., Neubert, S., Reich, K., Eds.; Waxmann: Münster, Germany; New York, NY, USA; Munich, Germany; Berlin, Germany, 2004; pp. 13–27, ISBN 9783830914068.
30. Kühne, O.; Berr, K. *Wissenschaft, Raum, Gesellschaft: Eine Einführung zur Sozialen Erzeugung von Wissen*; Springer VS: Wiesbaden, Germany, 2021.
31. Baltzer, U. Rorty und die Erneuerung des Pragmatismus. In *Hinter den Spiegeln: Beiträge zur Philosophie Richard Rortys mit Erwiderungen von Richard Rorty*; Tietz, T., Schäfer, U., Zill, R., Eds.; Suhrkamp: Frankfurt, Germany, 2001; pp. 21–48.
32. Rorty, R. *Hoffnung Statt Erkenntnis: Eine Einführung in Die Pragmatische Philosophie*; 3. Auflage; Passagen-Verlag: Vienna, Austria, 2018; [1994].

33. Dewey, J. *Die Öffentlichkeit und Ihre Probleme*; Philo Verlagsgesellschaft: Berlin, Germany, 1996; ISBN 3865720285.
34. Rorty, R. Erwiderung auf Hauke Brunkhorst. In *Hinter den Spiegeln: Beiträge zur Philosophie Richard Rortys mit Erwiderungen von Richard Rorty*; Tietz, T., Schäfer, U., Zill, R., Eds.; Suhrkamp: Frankfurt, Germany, 2001; pp. 162–165.
35. Topper, K. Richard Rorty, Liberalism and the Politics of Redescription. *Am. Political Sci. Rev.* **1995**, *89*, 954–965. [CrossRef]
36. Rorty, R. *Kontingenz, Ironie und Solidarität*; Suhrkamp: Frankfurt, Germany, 1989; ISBN 3-518-58012-4.
37. Deines, S. *Situierte Kritik: Modelle kritischer Praxis in Hermeneutik, Poststrukturalismus und Neopragmatismus*; Johann Wolfgang Goethe-Universität: Frankfurt, Germany, 2008.
38. Wittgenstein, L. *Tractatus Logico-Philosophicus: Tagebücher 1914–1916. Philosophische Untersuchungen*; Werkausgabe Band 1, 10. Auflage; Suhrkamp: Frankfurt, Germany, 1995; [1953].
39. Rorty, R. *Der Spiegel der Natur: Eine Kritik der Philosophie*; Suhrkamp: Frankfurt, Germany, 1981.
40. Rorty, R. Erwiderung auf Friederike Müller-Frimauth. In *Hinter den Spiegeln: Beiträge zur Philosophie Richard Rortys mit Erwiderungen von Richard Rorty*; Tietz, T., Schäfer, U., Zill, R., Eds.; Suhrkamp: Frankfurt, Germany, 2001; pp. 259–263.
41. Frazier, B. The ethics of Rortian redescription. *Philos. Soc. Crit.* **2006**, *32*, 461–492. [CrossRef]
42. Kühne, O.; Koegst, L.; Zimmer, M.-L.; Schäffauer, G. "... Inconceivable, Unrealistic and Inhumane": Internet Communication on the Flood Disaster in West Germany of July 2021 between Conspiracy Theories and Moralization—A Neopragmatic Explorative Study. *Sustainability* **2021**, *13*, 11427. [CrossRef]
43. Stemmer, B.; Bernstein, F.; Behre, E.; Kaußen, L. Naherholung als Teil der grünen Infrastruktur—Ein neopragmatischer Ansatz. In *Landschaft und Tourismus*; Kühne, O., Freytag, T., Sedelmeier, T., Jenal, C., Eds.; Springer: Wiesbaden, Germany, 2023; pp. 253–275.
44. Popper, K.R. *Alles Leben ist Problemlösen. Über Erkenntnis, Geschichte und Politik*; Piper: Munich, Germany, 1996.
45. Luhmann, N. *Soziale Systeme: Grundriß einer allgemeinen Theorie*; Suhrkamp: Frankfurt, Germany, 1984.
46. Luhmann, N. *Ökologische Kommunikation: Kann die Moderne Gesellschaft Sich auf Ökologische Gefährdungen Einstellen?* 3. Auflage; VS Verlag für Sozialwissenschaften: Opladen, Germany, 1990; [1986].
47. Bourdieu, P. *Distinction: A Social Critique of the Judgement of Taste*; Harvard University Press: Cambridge, MA, USA, 1984; ISBN 0674212800.
48. Bourdieu, P. Ökonomisches Kapital—Kulturelles Kapital—Soziales Kapital. In *Die verborgenen Mechanismen der Macht*; Bourdieu, P., Ed.; VSA: Hamburg, Germany, 2005; pp. 49–80, [1983].
49. Dahrendorf, R. *Der Moderne Soziale Konflikt: Essay zur Politik der Freiheit*; Deutsche Verlags-Anstalt DVA: Stuttgart, Germany, 1992; ISBN 3-421-06539-X.
50. Dahrendorf, R. *Konflikt und Freiheit: Auf dem Weg zur Dienstklassengesellschaft*; Piper: Munich, Germany, 1972; ISBN 978-3492017824.
51. Dahrendorf, R. *Soziale Klassen und Klassenkonflikt in der Industriellen Gesellschaft*; Enke: Stuttgart, Germany, 1957.
52. Popper, K.R. Three Worlds: Tanner Lecture, Michigan, April 7, 1978. *Mich. Q. Rev.* **1979**, *18*, 141–167. Available online: https://tannerlectures.utah.edu/_resources/documents/a-to-z/p/popper80.pdf (accessed on 20 December 2023).
53. Popper, K.R. *Objektive Erkenntnis: Ein Evolutionärer Entwurf*; Hoffmann und Campe: Hamburg, Germany, 1973; ISBN 3-455-09088-5.
54. Popper, K.R.; Eccles, J.C. *Das Ich und Sein Gehirn*; Piper: Munich, Germany, 1977; ISBN 3-492-02447-5.
55. Kühne, O. Landscape Conflicts: A Theoretical Approach Based on the Three Worlds Theory of Karl Popper and the Conflict Theory of Ralf Dahrendorf, Illustrated by the Example of the Energy System Transformation in Germany. *Sustainability* **2020**, *12*, 6772. [CrossRef]
56. Kühne, O. Die Landschaften 1, 2 und 3 und ihr Wandel: Perspektiven für die Landschaftsforschung in der Geographie—50 Jahre nach Kiel. *Berichte Geogr. Landeskd.* **2018**, *92*, 217–231.
57. Koegst, L. Über drei Welten, Räume und Landschaften: Digital geführte Exkursionen an Hochschulen aus der Perspektive der drei Welten Theorie im Allgemeinen und der Theorie der drei Landschaften im Speziellen. *Berichte Geogr. Landeskd.* **2022**, *69*, 1–21. [CrossRef]
58. Berr, K. Multisensuality Versus Visual Primacy of Landscape Perception. In *Multisensory Landscapes: Theories, Research Fields, Methods—An Introduction*; Koegst, L., Kühne, O., Edler, D., Eds.; Springer Fachmedien: Wiesbaden, Germany, 2023; pp. 49–71.
59. Zepp, H. Das Neue Emschertal. Transformation von Freiräumen und Veränderung von Ökosystemleistungen während der letzten 200 Jahre. In *Landschaft als Prozess*; Duttmann, R., Kühne, O., Weber, F., Eds.; Springer VS: Wiesbaden, Germany, 2020; pp. 327–360.
60. Eberhardt, A.K. Urban Landscapes in Boardgames. In *The Social Construction of Landscapes in Games*; Edler, D., Kühne, O., Jenal, C., Eds.; Springer: Wiesbaden, Germany, 2022; pp. 109–126.
61. Edler, D. Taunting Landscapes in Pinball Games. In *The Social Construction of Landscapes in Games*; Edler, D., Kühne, O., Jenal, C., Eds.; Springer: Wiesbaden, Germany, 2022; pp. 149–161.
62. Weichhart, P. Die Räume zwischen den Welten und die Welt der Räume. In *Handlungszentrierte Sozialgeographie: Benno Werlens Entwurf in Kritischer Diskussion*; Meusburger, P., Ed.; Steiner: Stuttgart, Germany, 1999; pp. 67–94, ISBN 3-515-07613-1.
63. Werlen, B. *Gesellschaft, Handlung und Raum: Grundlagen Handlungstheoretischer Sozialgeographie*; Steiner: Stuttgart, Germany, 1997; ISBN 3-515-04886-3.
64. Zierhofer, W. Geographie der Hybriden. *Erdkunde* **1999**, *53*, 1–13. [CrossRef]
65. Schafranek, M.; Huber, F.; Werndl, C. Die evolutionäre Grundlage Poppers Drei-Welten-Lehre: Eine unberücksichtigte Perspektive in der human-ökologischen Theoriendiskussion der Geographie. *Geogr. Z.* **2006**, *94*, 129–142.

66. Hard, G. Über Räume reden: Zum Gebrauch des Wortes "Raum" in sozialwissenschaftlichem Zusammenhang. In *Landschaft und Raum: Aufsätze zur Theorie der Geographie*; Hard, G., Ed.; Universitätsverlag Rasch: Osnabrück, Germany, 2002; pp. 235–252, ISBN 9783935326377.
67. Zierhofer, W. *Gesellschaft: Transformation Eines Problems*; Bibliotheks- und Informationssystem der Carl von Ossietzky Universität: Oldenburg, Germany, 2002; ISBN 3-8142-0803-X.
68. Werlen, B. Thesen zur handlungstheoretischen Neuorientierung sozialgeographischer Forschung. *Geogr. Helv.* **1986**, *41*, 67–76. [CrossRef]
69. Berger, P.L.; Luckmann, T. *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*; Anchor Books: New York, NY, USA, 1966; ISBN 0-385-05898-5.
70. Berger, P.L. *Einladung zur Soziologie: Eine Humanistische Perspektive*; 2. ergänzte Auflage; UVK Verlagsgesellschaft mbH; UVK/Lucius: Konstanz, Munich, Germany, 2017; ISBN 9783825248321. [1963].
71. Schütz, A.; Luckmann, T. *Strukturen der Lebenswelt*; UTB: Konstanz, Germany, 2003; ISBN 978-3825224127. [1975].
72. Schütz, A. *Der sinnhafte Aufbau der sozialen Welt: Eine Einleitung in die Verstehende Soziologie*; 2nd Auflage; Julius Springer: Vienna, Austria, 1960; [1932].
73. Greider, T.; Garkovich, L. Landscapes: The Social Construction of Nature and the Environment. *Rural. Sociol.* **1994**, *59*, 1–24. [CrossRef]
74. Kühne, O. *Landschaftstheorie und Landschaftspraxis: Eine Einführung aus Sozialkonstruktivistischer Perspektive*; 3. aktualisierte und überarbeitete Auflage; Springer VS: Wiesbaden, Germany, 2021.
75. Aschenbrand, E. Einsamkeit im Paradies. Touristische Distinktionspraktiken bei der Aneignung von Landschaft. *Berichte Geogr. Landeskd.* **2016**, *90*, 219–234.
76. Fontaine, D. *Simulierte Landschaften in der Postmoderne: Reflexionen und Befunde zu Disneyland, Wolfersheim und GTA V*; Springer VS: Wiesbaden, Germany, 2017; ISBN 978-3-658-16446-1.
77. Al-Khanbashi, M. *The Social Construction and Use of Landscape and Public Space in the Age of Migration: Arab Immigrants in Berlin*; Springer VS: Wiesbaden, Germany, 2020.
78. Stotten, R. *Das Konstrukt der Bäuerlichen Kulturlandschaft: Perspektiven von Landwirten im Schweizerischen Alpenraum*; Innsbruck University Press: Innsbruck, Germany, 2015; ISBN 9783902936714.
79. Drexler, D. Landscape, Paysage, Landschaft, Táj: The Cultural Background of Landscape Perceptions in England, France, Germany, and Hungary. *J. Ecol. Anthropol.* **2013**, *16*, 85–96. [CrossRef]
80. Ueda, H. A Study on Residential Landscape Perception through Landscape Image: Four Case Studies in German and Japanese Rural Communities. Inaugural Dissertation, University of Kassel: Kassel, Germany, 2010.
81. Makhzoumi, J.M. Borrowed or Rooted?: The Discourse of 'Landscape' in the Arab Middle East. In *Landscape Culture—Culturing Landscapes: The Differentiated Construction of Landscapes*; Bruns, D., Kühne, O., Schönwald, A., Theile, S., Eds.; Springer VS: Wiesbaden, Germany, 2015; pp. 111–126, ISBN 9783658042837.
82. Mead, G.H. *Mind, Self, and Society: From the Standpoint of a Social Behaviorist*; University of Chicago Press: Chicago, IL, USA, 1934.
83. Kühne, O. *Landscape and Power in Geographical Space as a Social-Aesthetic Construct*; Springer International Publishing: Dordrecht, The Netherlands, 2018; ISBN 3319729020.
84. Fontaine, D. Die Energiewende und ihr Einzug in saarländische Lehrwerke für Gymnasien: Eine Erfolgsgeschichte? In *Bausteine der Energiewende*; Kühne, O., Weber, F., Eds.; Springer VS: Wiesbaden, Germany, 2018; pp. 369–383. ISBN 978-3-658-19508-3.
85. Jenal, C. *"Das Ist Kein Wald, Ihr Pappnasen!"–Zur sozialen Konstruktion von Wald: Perspektiven von Landschaftstheorie und Landschaftspraxis*; Springer VS: Wiesbaden, Germany, 2019; ISBN 978-3-658-25713-2.
86. Wojtkiewicz, W. *Sinn—Bild—Landschaft: Landschaftsverständnisse in der Landschaftsplanung: Eine Untersuchung von Idealvorstellungen und Bedeutungszuweisungen*; Technische Universität Berlin: Berlin, Germany, 2015.
87. Kühne, O. *Distinktion–Macht–Landschaft: Zur Sozialen Definition von Landschaft*; VS Verlag für Sozialwissenschaften: Wiesbaden, Germany, 2008.
88. Stemmer, B.; Philipper, S.; Moczek, N.; Röttger, J. Die Sicht von Landschaftsexperten und Laien auf ausgewählte Kulturlandschaften in Deutschland—Entwicklung eines Antizipativ-Iterativen Geo-Indikatoren-Landschaftspräferenzmodells (AIGILaP). In *Landschaftskonflikte*; Berr, K., Jenal, C., Eds.; Springer VS: Wiesbaden, Germany, 2019; pp. 507–534.
89. Czepczyński, M. *Cultural Landscapes of Post-Socialist Cities: Representation of Powers and Needs*; Ashgate: Hampshire, UK; Burlington, IL, USA, 2008.
90. Gailing, L.; Leibenath, M. Political landscapes between manifestations and democracy, identities and power. *Landsc. Res.* **2017**, *42*, 337–348. [CrossRef]
91. Kühne, O.; Koegst, L. *Land Loss in Louisiana: A Neopragmatic Redescription*; Springer VS: Wiesbaden, Germany, 2023.
92. Hokema, D. Landscape is Everywhere. The Construction of Landscape by US-American Laypersons. *Geogr. Z.* **2015**, *103*, 151–170. [CrossRef]
93. Nowotny, H. Experten, Expertisen und imaginierte Laien. In *Wozu Experten? Ambivalenzen der Beziehung von Wissenschaft und Politik*; Bogner, A., Torgersen, H., Eds.; VS Verlag für Sozialwissenschaften: Wiesbaden, Germany, 2005; pp. 33–44.
94. Weber, F.; Jenal, C.; Roßmeier, A.; Kühne, O. Conflicts around Germany's *Energiewende*: Discourse patterns of citizens' initiatives. *Quaest. Geogr.* **2017**, *36*, 117–130. [CrossRef]

95. *The Ashgate Research Companion to Media Geography*; Adams, P.C.; Craine, J.; Dittmer, J. (Eds.) Routledge: London, UK; New York, NY, USA, 2018.
96. *Routledge Handbook of Media Geographies*; Adams, P.C.; Warf, B. (Eds.) Routledge: London, UK; New York, NY, USA, 2022.
97. Linke, S.I. *Die Ästhetik Medialer Landschaftskonstrukte: Theoretische Reflexionen und Empirische Befunde*; Springer VS: Wiesbaden, Germany, 2019; ISBN 978-3-658-25873-3.
98. Döring, J.; Thielmann, T. Mediengeographie: Für eine Geomedienwissenschaft. In *Mediengeographie: Theorie–Analyse–Diskussion*; Döring, J., Thielmann, T., Eds.; transcript: Bielefeld, Germany, 2009; pp. 9–64, ISBN 9783837610222.
99. Kaußen, L. Landscape Perception and Construction in Social Media: An Analysis of User-generated Content. *J. Digit. Landsc. Archit.* **2018**, *3*, 373–379. [CrossRef]
100. Purcell, D. The Internet. In *The Ashgate Research Companion to Media Geography*; Adams, P.C., Craine, J., Dittmer, J., Eds.; Routledge: London, UK; New York, NY, USA, 2018; pp. 137–152.
101. *Communications/Media/Geographies*; Adams, P.C.; Cupples, J.; Glynn, K.; Jansson, A.; Moores, S. (Eds.) Routledge: New York, NY, USA, 2017.
102. Fletchall, A.; Lukinbeal, C.; McHugh, K. *Place, Television, and the Real Orange County*; Franz Steiner Verlag: Stuttgart, Germany, 2012; ISBN 978-3-515-10118-9.
103. *Media's Mapping Impulse*; Lukinbeal, C.; Sharp, L.; Sommerlad, E.; Escher, A. (Eds.) Franz Steiner Verlag: Stuttgart, Germany, 2019; ISBN 978-3-515-12424-9.
104. Lukinbeal, C.; Sommerlad, E. Doing film geography. *GeoJournal* **2022**, *87*, 1–9. [CrossRef] [PubMed]
105. *Mediated Geographies and Geographies of Media*; Mains, S.P.; Cupples, J.; Lukinbeal, C. (Eds.) Springer: Dordrecht, The Netherlands; Berlin/Heidelberg, Germany; New York, NY, USA; London, UK, 2015.
106. Bernabeu-Bautista, Á.; Serrano-Estrada, L.; Perez-Sanchez, V.R.; Martí, P. The Geography of Social Media Data in Urban Areas: Representativeness and Complementarity. *Int. J. Geo-Inf.* **2021**, *10*, 747. [CrossRef]
107. *The Fight to Stay Put: Social Lessons through Media Images of Urban Transformation and Change*; Curti, G.H.; Craine, J.; Aitken, S.C. (Eds.) Franz Steiner Verlag: Stuttgart, Germany, 2013; ISBN 978-3-515-10212-4.
108. Kitchin, R.; Linehan, D.; O'Callaghan, C.; Lawton, P. Public geographies through social media. *Dialogues Hum. Geogr.* **2013**, *3*, 56–72. [CrossRef]
109. Kaußen, L. *Die Wahrnehmung von Landschaft in sozialen Medien: Eine Analyse von nutzergenerierten Inhalten*; Springer Fachmedien: Wiesbaden, Germany, 2021; ISBN 9783658353742.
110. *Handbuch Digitale Geographien: Welt–Wissen–Werkzeuge*; Bork-Hüffer, T.; Füller, H.; Straube, T. (Eds.) Brill Schöningh: Paderborn, Germany, 2021; ISBN 978-3-8252-5567-1.
111. Gold, J.R.; Gold, M.M. The field and the frame: Landscape, film and popular culture. In *The Routledge Companion to Landscape Studies*; 2nd Auflage; Howard, P., Thompson, I., Waterton, E., Atha, M., Eds.; Routledge: London, UK; New York, NY, USA, 2019; pp. 227–236, ISBN 9781315195063.
112. Lefebvre, M. (Ed.) *Landscape and Film*; Routledge: New York, NY, USA; London, UK, 2006; ISBN 978-0415975551.
113. Kühne, O.; Koegst, L. Neopragmatic Reflections on Coastal Land Loss and Climate Change in Louisiana in Light of Popper's Theory of Three Worlds. *Land* **2023**, *12*, 348. [CrossRef]
114. Koegst, L.; Kühne, O. Moving Baton Rouge—From Cinematic Representations, Phenomenological Approaches and Historical Developments of the 'Multivillage Metropolis'. In *Multisensory Landscapes: Theories, Research Fields, Methods—An Introduction*; Koegst, L., Kühne, O., Edler, D., Eds.; Springer Fachmedien: Wiesbaden, Germany, 2023; pp. 91–127.
115. Zonn, L. (Ed.) *Place Images in Media: Portrayal, Experience, and Meaning*; Rowman & Littlefield Publishers, Inc.: Savage, MD, USA, 1990.
116. Harendt, A. *Gesellschaft. Raum. Narration: Geographische Weltbilder im Medienalltag*; Franz Steiner Verlag: Stuttgart, Germany, 2019.
117. Burgess, J.A. News from Nowhere: The Press, the Riots and the Myth of the Inner City. In *Geography, the Media & Popular Culture*; Burgess, J., Gold, J.R., Eds.; St. Martin's Press: New York, NY, USA, 1985; pp. 192–228.
118. Rüthers, B. Einführung: Medien als vierte Gewalt. In *Vierte Gewalt? Medien und Medienkontrolle: 16. Baden-Württemberg-Kolloquium*; von Graevenitz, G., Köcher, R., Rüthers, B., Eds.; UVK-Medien: Konstanz, Germany, 1999; pp. 11–18.
119. Fröhlich, H. *Das Neue Bild der Stadt: Filmische Stadtbilder und Alltägliche Raumvorstellungen im Dialog*; Franz Steiner Verlag: Stuttgart, Germany, 2007; ISBN 3515090363.
120. Urry, J.; Larsen, J. *The Tourist Gaze 3.0*; SAGE Publications: Los Angeles, CA, USA; London, UK; New Delhi, India; Singapore; Washington, DC, USA, 2011.
121. Luhmann, N. *Die Realität der Massenmedien*; Westdeutscher Verlag: Opladen, Germany, 1996; ISBN 3-531-12841-8.
122. Olea, R.A.; Coleman, J.L. A Synoptic Examination of Causes of Land Loss in Southern Louisiana as Related to the Exploitation of Subsurface Geologic Resources. *J. Coast. Res.* **2014**, *297*, 1025–1044. [CrossRef]
123. Scaife, W.W.; Turner, R.E.; Costanza, R. Coastal Louisiana recent land loss and canal impacts. *Environ. Manag.* **1983**, *7*, 433–442. [CrossRef]
124. Craig, N.J.; Turner, R.E.; Day, J.W. Land Loss in Coastal Louisiana (U.S.A.). *Environ. Manag.* **1979**, *3*, 133–144. [CrossRef]
125. Colten, C.E. *State of Disaster: A Historical Geography of Louisiana's Land Loss Crisis*; Louisiana State University Press: Baton Rouge, LA, USA, 2021; ISBN 9780807175705.

126. Colten, C.E. Cartographic Depictions of Louisiana Land Loss: A Tool for Sustainable Policies. *Sustainability* **2018**, *10*, 763. [CrossRef]
127. Bernier, J. Trends and Causes of Historical Wetland Loss in Coastal Louisiana. Available online: https://pubs.usgs.gov/fs/2013/3017/ (accessed on 18 February 2021).
128. Shusterman, R. *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics*; Repr.; Cambridge University Press: Cambridge, UK, 2011; ISBN 9780521675871.
129. Shusterman, R. *Pragmatist Aesthetics: Living Beauty, Rethinking Art*; Blackwell Publishers: Oxford, UK, 1992.
130. Molnar, P.H. *Plate Tectonics: A Very Short Introduction*; Oxford University Press: Oxford, UK, 2015; ISBN 9780198728269.
131. Dokka, R.K. The role of deep processes in late 20th century subsidence of New Orleans and coastal areas of southern Louisiana and Mississippi. *J. Geophys. Res.* **2011**, *116*, 1–25. [CrossRef]
132. Dokka, R.K. Modern-day tectonic subsidence in coastal Louisiana. *Geology* **2006**, *34*, 281–284. [CrossRef]
133. Rogers, J.D.; Boutwell, G.; Watkins, C.; Karadeniz, D. Geology of the New Orleans Region. In *Investigation of the Performance of the New Orleans Flood Protection Systems in Hurricane Katrina on August 29, 2005: Final Report Volume II: Appendices*; Seed, R.B., Bea, R.G., Abdelmalak, R.I., Athanasopoulos, A.G., Boutwell, G.P., Bray, J.D., Briaud, J.-L., Cheung, C., Cabos-Roa, D., Cohen-Waeber, J., et al., Eds.; Self-Publishing: New Orleans, LA, USA, 2006; pp. III1–III49.
134. Beatley, T. *Planning for Coastal Resilience: Best Practices for Calamitous Times*; Island Press: Washington, DC, USA, 2009; ISBN 9781597265621.
135. Kolb, C.R.; Saucier, R.T. Engineering Geology of New Orleans. In *Geology under Cities*; Legget, R.F., Ed.; Geological Society of America: Boulder, CO, USA, 1982; pp. 75–93.
136. Heinrich, P.V.; Miner, M.; Paulsell, R.; McCulloh, R.P. *Response of Late Quaternary Valley Systems to Holocene Sea Level Rise on Continental Shelf Offshore Louisiana: Preservation Potential of Paleolandscapes*; U.S. Department of the Interior: Baton Rouge, LA, USA, 2020.
137. Barras, J.A. *Land Area Change and Overview of Major Hurricane: Impacts in Coastal Louisiana, 2004-08*; U.S. Department of the Interior: Reston, VA, USA, 2009.
138. Swenson, D. These Six Factors Explain Why Louisiana Is Rapidly Losing Land, 31 May 2021. NOLA.com. Available online: https://www.nola.com/news/article_59675b8c-bfbe-11eb-9602-47cf4c0429dc.html (accessed on 2 December 2021).
139. Mousavi, M.E.; Irish, J.L.; Frey, A.E.; Olivera, F.; Edge, B.L. Global warming and hurricanes: The potential impact of hurricane intensification and sea level rise on coastal flooding. *Clim. Change* **2011**, *104*, 575–597. [CrossRef]
140. Cahoon, D.R.; Reed, D.J.; Day, J.W.; Steyer, G.D.; Boumans, R.M.; Lynch, J.C.; McNally, D.; Latif, N. The Influence of Hurricane Andrew on Sediment Distribution in Louisiana Coastal Marshes. *J. Coast. Res.* **1995**, *Special Issue 21*, 280–294.
141. Turner, R.E.; Baustian, J.J.; Swenson, E.M.; Spicer, J.S. Wetland sedimentation from hurricanes Katrina and Rita. *Science* **2006**, *314*, 449–452. [CrossRef] [PubMed]
142. Barras, J.A. Land Area Changes in Coastal Louisiana: After Hurricanes Katrina and Rita. In *Science and the Storms: The USGS Response to the Hurricanes of 2005*; Farris, G.S., Smith, G.J., Crane, M.P., Demas, C.R., Robbins, L.L., Lavoie, D., Eds.; Government Printing Office: Reston, VA, USA, 2007; pp. 97–102, ISBN 9780160867149.
143. Couvillion, B.R.; Barras, J.A.; Steyer, G.D.; Sleavin, W.; Fischer, M.; Beck, H.; Trahan, N.; Griffin, B.; Heckman, D. Land Area Change in Coastal Louisiana from 1932 to 2010. Available online: https://pubs.usgs.gov/sim/3164/downloads/SIM3164_Pamphlet.pdf (accessed on 24 January 2020).
144. Glick, P.; Clough, J.; Polaczyk, A.; Couvillion, B.; Nunley, B. Potential Effects of Sea-Level Rise on Coastal Wetlands in Southeastern Louisiana. *J. Coast. Res.* **2013**, *63*, 211–233. [CrossRef]
145. Kolker, A.S.; Alison, M.A.; Hameed, S. An evaluation of subsidence rates and sea-level variability in the northern Gulf of Mexico. *Geophys. Res. Lett.* **2011**, *38*, 1–6. [CrossRef]
146. Coastal Protection and Restoration Authority of Louisiana. *2023—Louisiana's Comprehensive Master Plan for a Sustainable Coast: Effective*; Coastal Protection and Restoration Authority: Baton Rouge, LA, USA, 25 May 2023.
147. Coastal Protection and Restoration Authority. CPRA Master Plan Data Viewer: Land Change. Available online: https://cims.coastal.la.gov/masterplan/GISDownload/ (accessed on 5 February 2024).
148. Coastal Protection and Restoration Authority of Louisiana. Louisiana's Comprehensive Master Plan for a Sustainable Coast: Effective. 2 June 2017. Available online: http://coastal.la.gov/wp-content/uploads/2017/04/2017-Coastal-Master-Plan_Web-Book_CFinal-with-Effective-Date-06092017.pdf (accessed on 24 August 2021).
149. Mayring, P. Qualitative Inhaltsanalyse. *FQS–Forum Qual. Sozialforschung* **2000**, *1*, 28. [CrossRef]
150. Kuckartz, U.; Rädiker, S. *Qualitative Inhaltsanalyse: Methoden, Praxis, Computerunterstützung*; 5. [überarbeitete] Auflage; Beltz Juventa: Weinheim, Germany, 2022; ISBN 9783779962311.
151. Cope, M.; Hay, I. Where are we now? Qualitative Research in Human Geography. In *Qualitative Research Methods in Human Geography*, 15th ed.; Hay, I., Cope, M., Eds.; Oxford University Press: Ontario, CA, USA, 2021; pp. 1–17.
152. Stratford, E.; Bradshaw, M. Rigorous and Trustworthy: Qualitative Research Design. In *Qualitative Research Methods in Human Geography*, 15th ed.; Hay, I., Cope, M., Eds.; Oxford University Press: Ontario, CA, USA, 2021; pp. 92–106.
153. Reuber, P.; Pfaffenbach, C. *Methoden der Empirischen Humangeographie: Beobachtung und Befragung*; Westermann: Braunschweig, Germany, 2005.
154. Thelwall, M.; Sud, P.; Vis, F. Commenting on YouTube videos: From guatemalan rock to El Big Bang. *J. Am. Soc. Inf. Sci.* **2012**, *63*, 616–629. [CrossRef]

155. Kittler, T. Mediendiskurs zum Klimawandel in Louisiana—Eine quantitative Analyse von YouTube-Kommentaren. In *Louisiana–Mediengeographische Beiträge zu Einer Neopragmatischen Regionalen Geographie*; Kühne, O., Sedelmeier, T., Jenal, C., Eds.; Springer: Wiesbaden, Germany, 2021; pp. 167–181.
156. Pearce, W.; Niederer, S.; Özkula, S.M.; Sánchez Querubín, N. The social media life of climate change: Platforms, publics, and future imaginaries. *WIREs Clim. Change* **2019**, *10*, 1–13. [CrossRef]
157. Chi, Y.N. Modeling and Forecasting Long-Term Records of Mean Sea Level at Grand Isle, Louisiana: SARIMA, NARNN, and Mixed SARIMA-NARNN Models. *J. Appl. Data. Sci.* **2021**, *2*, 1–13. [CrossRef]
158. Penland, S.; Connor, P.F.; Beall, A.; Fearnley, S.; Williams, S.J. Changes in Louisiana's Shoreline: 1855–2002. *J. Coast. Res.* **2005**, *Special Issue 44*, 7–39.
159. Martinez, L.; O'Brien, S.; Bethel, M.; Penland, S.; Kulp, M. *Louisiana Barrier Island Comprehensive Monitoring Program (BICM) Volume 2: Shoreline Changes and Barrier Island Land Loss 1800's–2005*; University of New Orleans, Pontschartrain Institute for Environmental Sciences: New Orleans, LA, USA, 2009.
160. Irish, J.L.; Frey, A.E.; Rosati, J.D.; Olivera, F.; Dunkin, L.M.; Kaihatu, J.M.; Ferreira, C.M.; Edge, B.L. Potential implications of global warming and barrier island degradation on future hurricane inundation, property damages, and population impacted. *Ocean. Coast. Manag.* **2010**, *53*, 645–657. [CrossRef]
161. Clipp, A.; Gentile, B.; Green, M.; Galinski, A.; Harlan, R.; Rosen, Z.; Saucier, M. Coastal Master Plan: Appendix B: People and the Landscape.: Version Final. Available online: http://coastal.la.gov/wp-content/uploads/2017/04/Appendix-B_People-and-the-Landscape_FINAL.pdf (accessed on 31 May 2022).
162. Müller, M. *Private Romantik, öffentlicher Pragmatismus?: Richard Rortys Transformative Neubeschreibung des Liberalismus*, 1st ed.; Transcript Verlag: Bielefeld, Germany, 2014; ISBN 9783839420416.
163. Schubert, H.-J.; Joas, H.; Wenzel, H. *Pragmatismus zur Einführung: Kreativität, Handlung, Deduktion, Induktion, Abduktion, Chicago School, Sozialreform, Symbolische Interaktion*; Junius Verlag: Hamburg, Germany, 2010; ISBN 3885066823.
164. Steiner, C. *Pragmatismus–Umwelt–Raum: Potenziale des Pragmatismus für Eine Transdisziplinäre Geographie der Mitwelt*; Franz Steiner Verlag: Stuttgart, Germany, 2014; ISBN 9783515108829.
165. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Adm. Policy Ment. Health* **2015**, *42*, 533–544. [CrossRef] [PubMed]
166. Live Storms Media. 8-31-2021 Grand Isle, La Hurricane Ida Aftermath- Widespread Destruction-Drone. Available online: https://www.youtube.com/watch?v=k30jEs2p1PM&t=111s (accessed on 1 November 2023).
167. Schreier, M. Varianten qualitativer Inhaltsanalyse: Ein Wegweiser im Dickicht der Begrifflichkeiten. *FQS–Forum Qual. Sozialforschung* **2014**, *15*, 27. [CrossRef]
168. Girtler, R. *10 Gebote der Feldforschung*; LIT Verlag: Vienna, Austria, 2004.
169. Flick, U. *Qualitative Sozialforschung: Eine Einführung*; Rowohlt: Reinbek, Germany, 2007; ISBN 9783499556944.
170. Mayring, P. *Einführung in die Qualitative Sozialforschung: Eine Anleitung zu Qualitativem Denken*; 7. Überarbeitete Auflage; Beltz: Weinheim, Germany; Basel, Swizerland, 2023; ISBN 9783407257345.
171. Coastal Protection and Restoration Authority. CIMS GIS Download: LA Coastal Area. Available online: https://cims.coastal.la.gov/Viewer/GISDownload.aspx (accessed on 16 August 2023).
172. U.S. Geological Survey. 1:1,000,000-Scale Waterbodies and Wetlands of the United States. Available online: https://purl.stanford.edu/sv709xw7113 (accessed on 20 December 2023).
173. Mayring, P.; Fenzl, T. Qualitative Inhaltsanalyse. In *Handbuch Methoden der Empirischen Sozialforschung*; Baur, N., Blasius, J., Eds.; Springer VS: Wiesbaden, Germany, 2014; pp. 543–556, ISBN 978-3-531-17809-7.
174. Mayring, P. *Qualitative Inhaltsanalyse: Grundlagen und Techniken*; 11th aktualisierte und überarb. Aufl; Beltz: Weinheim, Germany, 2010; ISBN 9783407255334.
175. Lambert, C.E.; Holley, J.R.; McComas, K.A.; Snider, N.P.; Tucker, G.K. Eroding Land and Erasing Place: A Qualitative Study of Place Attachment, Risk Perception, and Coastal Land Loss in Southern Louisiana. *Sustainability* **2021**, *13*, 6269. [CrossRef]
176. Weber, A.-M. The Social Construction of Land Loss in Louisiana. In *Landscape Conflicts*; Kühne, O., Berr, K., Koegst, L., Eds.; Springer VS: Wiesbaden, Germany, 2024; Forthcoming.
177. Weber, A.-M. Akzeptanz der Öl- und Gasindustrie in Louisiana. *Bericht Dtsch. Landeskd.* **2023**, *96*, 300–315. [CrossRef]
178. Burley, D.M. *Losing Ground: Identity and Land Loss in Coastal Louisiana*; University Press of Mississippi: Jackson, MI, USA, 2010.
179. Associated Press. 2 Louisiana Insurance Companies Fail after Hurricane Ida. Available online: https://www.bloomberg.com/news/articles/2021-12-05/2-louisiana-insurance-companies-fail-after-hurricane-ida (accessed on 22 February 2024).
180. Kasakove, S. For Storm Victims, Rebuilding Becomes the Disaster After the Disaster. Available online: https://www.nytimes.com/2022/02/27/us/hurricane-damage-insurance.html (accessed on 22 February 2024).
181. Kühne, O. Landscape Conflicts around the Energy Transition in Germany in the Light of Confict Theory and Popper's Three Worlds Theory. In *Oltre la Convenzione: Pensare, Studiare, Costruire il Paesaggio Vent'anni Dopo*; Castiglioni, B., Puttilli, M., Tanca, M., Eds.; Società di Studi Geografici: Firenze, Italy, 2021; pp. 1222–1232, ISBN 9788890892677.

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Article

The Treacherous Road to Sustainable Agriculture: Lessons from Israeli Farmers and the Need to Upscale the Debate

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Abstract: The current global agrifood system is increasingly fragile and despite a plethora of scientific research, progress in national and global policies setting commendable goals towards more sustainable agriculture is still sluggish. This paper argues that if the efforts continue to concentrate on farmers and rest solely on "fixing" modes of production at the farm level, the chances of arriving at significant changes are meagre. By conjugating Lefebvre's triad of spaces and geographic explorations on politics of scale with data harvested over three years of qualitative research in farms, this paper explores Israeli farmers' conduct in the field as they face many challenges at various scales. The paper presents their vulnerability against forces on a multiscalar level which present numerous obstacles in operating their farms. Addressing these challenges to allow them to integrate more sustainable modes of operation would require upscaling the debate and the taking of responsibility from all stakeholders concerned, from the farm level to global players.

Keywords: social space; Lefebvre's triad; scale and scalar politics; qualitative methods; conventional agriculture sustainable agriculture; family farms; small scale farms; Israel

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1. Introduction

Unsustainable food production and consumption patterns are a common thread running through many of the greatest challenges facing humanity today [1]. The existing global agrifood system is fragile [2–4]. This is, among other things, a direct outcome of modern, industrialized agriculture land-use practices that, since their early beginnings, have traded short-term increases in agricultural productivity and profit for long-term losses in ecosystem services [5]. This rather explains the pivotal and destructive role modern, industrialized agriculture plays in the current environmental crisis and its negative "contribution" on various fronts [6,7], among them increased gas emission [8], rapid deforestation [9], water pollution [10], water scarcity [11], and of course soil depletion and degradation [12].

In recent years the amount of data produced that affirms these problems in our agrifood system has accumulated in staggering quantities. This is also apparent in numerous literature reviews (some in this very journal) of more refined and specific topics which yield thousands of relevant studies e.g., Refs. [13–16]. And yet, against the exhaustive body of works and policies already implemented, the stubborn reality on the ground proves to be almost impervious to significant changes towards a more sustainable agriculture [17–19].

This conundrum is addressed in this paper, in which I ask the following: why is it that, despite ample approachable data and existing policies promoting more sustainable modes of production in the agrifood system, changes among farmers from across the globe are very slow to arrive? Particularly, the paper focuses on Israeli farmers who, due to the changing landscape of the Israel political economy, are receiving less subsidies and direct funding in comparison to farmers from other OECD countries (Interview with A., an official in the Israeli Ministry of Agriculture, 18 June 2023). My overarching argument is that, regardless of what is taking place in scales above and beyond the farm level, farmers find themselves on a very local and individual basis constrained and confronted by complex matrices of

challenges, which ultimately renders them vulnerable to today's market economy. This situation ultimately prevents most of them from integrating more sustainable modes in their fields.

Various methods were harnessed to bring to the fore the voices of Israeli farmers as they negotiate current challenges in the agrifood system. This enabled better understanding of their sense of place and the numerous factors that influence their conduct in the field and the challenges they face. This is executed, as explained below, by conjugating the Lefebvreian triad of social space and the politics of scale as explanatory mechanisms with farmers' conducts. This theoretical construction explains both the horizontal (what is taking place at farm level) and vertical (multiscalar levels, i.e., local to global) forces that ultimately spatialize at the farm and constitute farmers' approach to agriculture and conduct on the farm.

The purposes of this paper are threefold: First, to provide a theoretical background against which to explain the complex matrices farmers confront and negotiate in their respective fields. Second, to allow the voices of farmers and their daily and mundane struggles for survival to be heard. Third, to suggest that human geographers may take a more active role by engaging with stakeholders at all levels to promote policies and understandings that ultimately affect positive changes in our relations with our agrifood system. Put differently, and as recently suggested by Cirella et al., this means "to increase sustainability-based know-how and force a human–nature relations dialogue between the philosophical, economic, and urban arguments human beings toil with in modern society" [20] (p. 17).

The paper begins with a material and methods section that presents the theoretical background of "social space" and "scale politics", provides a short analysis of the variegated vocabulary of contemporary agriculture(s) and the unique political economy of agriculture in Israel and ends with an explanation of the research design and methodology. This is followed by a results and discussion section which presents the findings and engages with an analysis of Israeli farmers' perceptions and the challenges confronting them, arranged into themes. The conclusions section offers more general insights and relates to the role human geographers may take towards a more fruitful debate on promoting sustainable agriculture and connecting stakeholders at various scales.

2. Materials and Methods

2.1. Social Space and Lefebvre's Triad of Spaces

Lefebvre's conception of space was heavily explored as it offers a highly suggestive critical ontological framework for explaining spatial dynamics [21–24]. Nevertheless, his contribution to the understanding of space is largely overlooked in the context of agrifood systems. However, it does have tremendous potential and presents valuable opportunities for further explorations [25]. The model offers insights into the dynamic processes through which space is created, rationalized, embodied, and experienced. One significant contribution of Lefebvre's spatial ontology is the notion that social life is not confined to space; rather, it constitutes space itself. Therefore, space is in a constant state of production, reproduction, and transformation through social relations and activities [26]. Consequently, when examining agriculture, it is essential to view it not as a system operating in a neutral environment, but as an active process that both produces and rationalizes space through specific modes of production and conceptualization.

Lefebvre proposes a model that sees place not only as the sum of the individual's interpretation of their spatial experience but as a meeting point between the physical, mental, and social aspects of the produced space. Lefebvre's model distinguishes between three interrelated fields: the space perceived physically through the senses of our bodies (spatial practice), the space of understanding and professional knowledge (representations of space), and the space which is directly experienced and lived through its associated images and symbols (lived space or spaces of representations) [27]. The first field is the space perceived by the individual in terms of its physical organization and use. It is the

space where daily activities take place and is used for spatial experiences. In this way, physical spatial patterns are produced that correspond to the activities of production and consumption in a given society. The second field relates to the space of understanding and professional knowledge and is involved in the intellectualization of space. It is where researchers/professionals/policymakers express their insights through representations that reflect the knowledge generated in relation to space. This knowledge is not necessarily objective, and may well reflect the ideological and cultural/professional biases of the researcher. For example, completely contradictory scholarly perceptions can be suggested in the current context of the need to transition to a more environmentally friendly agriculture [28–30]. This also means to suggest that each part of the triad is certainly not homogenous, which rather complicates the matrices which are ultimately spatialized as social space. The third field consists of spaces of representation, which are the physical or virtual spaces where representations of space are produced, circulated, and consumed. These spaces of representation are crucial for the reproduction or transformation of social space and, as such, often become sites of struggle where different groups and ideologies compete over the meaning, and ultimately the uses, of space.

2.2. Scale and Scalar Politics: Towards an Understanding of Multiscalar Politics at Farm Level

Scale is a highly charged geographical concept. Following the emergence of a retheorized human geography, attention has increasingly been drawn to the relations between processes operating at different geographical scales (from the local to the global) and the ways they inform each other [31]. Taylor's seminal work emphasized the social construction of scale [32]. He suggested that people's experiences of everyday life were mediated through factors found on different scales [33]. Therefore, scalar arrangements are constantly being made and remade in response to different social actors pursuing specific political agendas [34]. They are rather flexible, as they are constantly in historical motion against socio-political and surely economic processes [35]. Put plainly, global, national, or local players can have an immense influence on where and on what scale the debate about environmentalism in agriculture and farmers' role within it takes place.

A crucial development in scale theory was made by Smith, who introduced what is now a common currency, i.e., scalar politics, alternatively known as "politics of scale" [36]. This take on scale is a way to grasp the complex interplay of existing power structures and political struggles, in which scale is used not only as a mechanism of constraint and exclusion but also as a weapon of expansion and inclusion. Scales are interconnected, mutually influenced, and relational, from the farm level to the global. More importantly, it is imperative to acknowledge the different spatial politics and decision-making processes at every level [37]. Therefore, scale and scaling are not politically neutral. They are both the result and the outcome of struggles for power and control. Scale demarcates the site of social or political contest. Jumping scales, for example, allow the actors to dissolve spatial boundaries that are largely imposed from above and that contain, rather than facilitate, their production and reproduction of everyday life [38]. In the context explored in this article, scale dynamics are imperative to explain challenges, obstacles, and surely motivation to move towards a more sustainable mode in the fields at the farm level against threats, demands, and constraints. However, this paper also aims to demonstrate how problems at the farm level may impose significant challenges, as they already do on multiscalar levels. At the end of the day, steps towards a more sustainable agriculture within this complex matrix, constituted at different scales, are spatialized only at the farm level.

2.3. Contemporary Agriculture: A Very Short Guide for the Perplexed and the Political Economy of Israeli Farmers

2.3.1. The Importance of Family and Small-Scale Farms

The incredible diversity of agricultural practices worldwide is a testament to the vast array of societies, technologies, and cultural landscapes that exist on the world stage. From traditional techniques to technologically advanced modes of operation, agricultural

systems to date encompass a wide spectrum. They represent distinct stages of agricultural transformation, contingent upon their technological advancements, market connectivity, and the evolving structures of national economies across the globe [39]. And yet, and even against the enormous changes that have radically transformed the face of modern agriculture, at the core of the world's agricultural production still stands, as it has since the Neolithic revolution, the family-owned small-scale farm [40–42]. This is precisely the reason why the FAO 2014 resolution stressed the importance of family farming for "its significant role in eradicating hunger and poverty, providing food security and nutrition, improving livelihoods, managing natural resources, protecting the environment, and achieving sustainable development". Family farms are perceived to be essential to sustaining these many functions, yet the very existence of family farms is reputedly under threat [43–45].

2.3.2. The Many Faces of Contemporary Agriculture

A rigorous and exhaustive discussion of all types of agriculture practiced today at the farm level far exceeds the scope of this paper and surely my survey here is extremely reductive. Therefore, in what follows I present a very concise outline of the emergence of different types of agriculture following the dramatic changes engendered by the growing reliance on fossil fuel energy and mechanization from the late 19th century to the present [46].

The integration of new machinery and later, industrialized cum chemical fertilizers, radically changed traditional agrarian practices from the late 19th century onwards, at first mostly in European countries. The most revolutionary change in agriculture occurred after World War II. From the mid-1940s to the late 1960s, agricultural support technologies were adapted for production, including inventions developed for use in the World Wars and the farm machinery that produced them. This led to advanced field mechanization, chemical substances for fertilization and pest control, as well as emergence of modified seeds [29]. These changes, supported and funded by governmental policies in Europe and the United States as part of the post-war recovery, were instrumental in the development of modern agriculture. Thus, the foundation of the "Green Revolution", which fundamentally transformed the face of world agriculture, and indeed of the world, was laid [47,48]. The agriculture that developed because of this revolution (1940s–1970s) is usually labeled as intensive or industrial agriculture. Since it became the predominant agricultural practice worldwide, it is often referred to as conventional agriculture [49].

However, like any revolution, the roots of the counterrevolution were already embedded within it. As concisely suggested by Moss and Bitman, "land cultivation in the 'developed' world was carried out and managed as if there was no need to consider nature and the environment at all" [50]. Thus, against the rapid spread of conventional agriculture there arose alternative views and modes of agriculture aiming to reduce its hazardous impacts [51]. As early as the 1920s, the organic option was presented as an alternate system, initially in Europe [52]. Since then, a wide range of alternative modes of agriculture under various heading have appeared, such as agroecology, ecoagriculture, sustainable, alternative, agroforestry, biodynamic, permaculture, holistic management (Savory's method), and lately, regenerative agriculture has become more and more prevalent in both scientific and farmers' discourse [53–55]. Without getting into the variations and nuances among the different types, they all aim to propose a way out of the prevailing conventional agriculture and the environmental hazards following in its wake. That said, it is not a dichotomic situation and some of the methods on offer are both discursive and also operate using conventional methods [56].

This is surely but a rudimentary and far-from-exhaustive analysis. Nonetheless its main objectives are to demonstrate the problematics of the field that farmers have to confront, absorb, and ultimately respond to and to demonstrate the existing axis of alternatives for farmers, ranging from conventional agriculture with its extreme negative

environmental impacts to different types of sustainable agriculture which usually involve more constraints and a higher initial economic investment from the farmer.

2.3.3. The Political Economy of Israeli Agriculture

Since the establishment of Israel in 1948 agriculture has played a significant role in the development and self-sufficiency of the state. Agriculture in Israel was closely intertwined with Zionism, the Jewish national movement [57]. Jewish pioneers played a crucial role in physically asserting the Zionist aspiration for a national territory and enjoyed tremendous social prestige and were supported accordingly with state subsidies, protectionism, and other kinds of aid [58]. The Israeli government has played a crucial role in supporting and advancing the agricultural sector. This support was manifested through various means, including the provision of subsidies, grants, and favorable loan conditions to farmers [59]. However, with the liberalization of the Israeli economy since the late 1970s, there has been a fundamental shift in the dominant political ideology. Consequently, farmers began to encounter growing economic hardships as the political supporting structures that were once central to their operations lost their hegemonic status and access to national budgets [60]. This policy shift and declining government intervention have presented grave challenges for farmers, requiring them to adapt to new economic realities and seek alternative means of support and sustainability.

The rise of the conservative right to political power in Israel shifted governmental attention and budgets to the needs of other sectors and populations [61]. This is particularly true regarding the growing colonization project in the Occupied Territories, in which the government encourages Israeli farmers to settle by means of substantial subsidies. During the late 1990s, governmental support for agriculture dropped to half its previous level [62]. As a response to these changes, many farmers have gradually diversified their livelihood by introducing new land uses in their farms. This liberalization process has also opened the technologically sophisticated, productive Israeli agricultural sector to global markets for its goods. A notable example is the Arava region, which relies almost exclusively on export of fresh produce to global markets [63]. This reorganization of the Israeli agriculture market also drove mostly small-scale farmers to sell or to find additional occupations to sustain their families. Thus, while some large agricultural corporations expand, small farmers struggle to survive [64,65]. In my ethnographies in the fields and interviews with farmers, most of them referred to their growing difficulties as they fight an uphill battle not only against market forces, rising prices of machines, fertilizers, water, and energy but also against dwindling public support and, at times, what they perceive as hostile governmental policies.

2.4. Research Design

2.4.1. Research Method and Data Collection

This study was based on a mixed methodology of diverse complimentary qualitative methods that together facilitated an understanding of farmers' spatial practice, that is, the way they understand and consequently manage their farm.

The first method employed was a survey of social media (mostly Facebook pages and groups) operated by farmers. This was executed mostly through 2020, during which an exhaustive literature survey of the different types of agriculture, critiques of current policies, and farmers' conduct in the field complemented this initial stage of data harvesting.

The second method involved ethnographic work in the form of participant observation and open-ended semi-structured interviews, which were conducted at farms over a 3-year period (2021 through 2023). Open-ended interviews serve as the optimal way to comprehend farmers' worldview, understanding of the situation, and surely their grounded knowledge. The interviews were not scripted and allowed farmers' voices and worldviews to emerge. However, the following key points and themes were followed and presented as questions during the interviews (Table 1):

- Personal data.
- Knowledge and sources of knowledge concerning farming/agriculture.
- Daily routine and conduct in the field.
- Interaction with scales beyond the farm level (state agencies, global markets, regulations, etc.).
- Approach to sustainability.
- Challenges, obstacles, and future goals in operating the farm.

Table 1. Aggregated data on interviewees and farms.

Age	Gender	Type of Farming	Location of Farms	Type of Typical Crops at Farms (Not Following Location)
Age range: 28–72	7 females	27 conventional	Golan Heights 12	Mixed farms 4
Average age 55	28 males	8 sustainable/ regenerative	Upper Galilee 7	Olives/avocado/mango 15
			Lower Galilee 8	Citrus 4
			Jezreel Valley 5	Deciduous (apples, almonds, pears, etc.) 8
			Sharon Plain 3	Cattle ranch 4

This was complemented by interviews with officials, mostly at the Israeli Ministry of Agriculture and Ministry of Environment Protection, and with researchers working on issues concerning Israeli agriculture at large. The third method involved was attending conferences, webinars, and Zoom meetings designated for farmers and mostly organized by farmers or NGOs promoting sustainable methods in agriculture. Below is a short explanation of each method:

- Literature Survey of social media: Like other sectors, farmers also engage with social media, within which the groups and pages followed were occupied with sharing information about crops, comparing prices, and at times bringing to the fore problems they were facing, such as the current increase in agricultural terrorism throughout Israel. In the local Israeli context, this term relates to agricultural crime (theft, sabotage, and extortion payments), which farmers consider fundamental threats to their economic and social survival. This was highly beneficial at the early stage of the project, as it enabled me to contact farmers directly and introduce myself and the project and later get access to the farmer and his/her field.
- Ethnographic fieldwork: This study is based in part on intensive ethnographic fieldwork conducted in farms and fields between 2021 and 2023. Over a three-year period, I contacted farmers and got permission to work in their fields. The work, carried out at 35 farms, lasted from a few hours to an entire day. In addition to working in the field, the fieldwork also consisted of participant observation and open-ended semi-structured interviews with farm owners. The three modes of data collection are further explained below:

Participant observation and ethnography: Data collection involved full researcher involvement in activities conducted at the farms explored. To document these observations, a field diary was conducted which was complemented by visual documentation of various activities and encounters at the farms. Additionally, informal talks with the farmer while at work were regularly carried out.

Open-ended interviews: To better understand the farmers' worldview and logic while operating the farm, I conducted interviews with the farmers, usually at the end of the day when work was done. A total of 35 farmers were interviewed. In this project, the focus was mostly on the way farmers perceive their work, indeed at times their ideology; and to learn

more about their professional knowledge and what their sources of information are, such as other farmers, professional guides from the ministry, going online, and more. In accordance with the paper's main objective, close attention was paid to the ways they formulate the challenges and obstacles they face as they operate their farm and what prevents them from going sustainable should they consider it. This was important for understanding the gaps between ideologies, convictions, and the practical principles that dictate operations in the field. This was conducive to understand better farmers' sense of place and responses to the scholarly and official discourses (policy, regulations, and professional knowledge) on agriculture.

2.4.2. Data Analysis

After summarizing all the data collected using the different methods, the main themes emerging from the field were aggregated inductively. To further refine these themes, I conflated my conclusions and interpretations with some of the farmers (usually a phone conversation but at times going back to the field) but, more importantly, also with officials and researchers from different disciplines who are intimate with Israeli agriculture. The interviews gave me answers to the questions that dealt with perceptions, attitudes, feelings, and thoughts, and enabled me to explore ontological aspects of farming—those that can be best understood through experience and actual presence in the social world of agriculture.

3. Results and Discussion

Increasing the resilience of agricultural landscapes requires fundamental changes to the dominant production model [66]. The accepted wisdom is that this can be achieved should farmers integrate sustainable forms of agriculture. Indeed, many explorations engaged with farmers' knowledge and the imperative of adopting sustainable methods as crucial to such transformations, e.g., [14,67–69]. And yet, if we are to accept that scale is relational, concentrating on what Agnew defined as "the local trap" of scale is only muddying the already murky waters [70]. Focusing solely on the farm level without accepting that scale is simultaneously fixed and fluid is disadvantageous to our current endeavors. This approach tends to downplay (or ignore) multiscalar politics and how many factors come into play and influence the outcome at the farm level, that is, what type of agriculture is being operated. Following Brenner, I contend that one must examine a range of scales at once (rather than focusing on a single scale alone) and the changing interrelationships among the various scales [71]. Farmers do not operate exclusively on the local scale; they do exist in a complex world. Cultural, economic, social, political, and surely environmental conditions influence what is spatialized at the farm level. Furthermore, it needs to be acknowledged that scale politics and scales are always relational; therefore, an analysis of a single scale alone is bound to miss out on the relationships among scales [72–74].

3.1. Lessons from the Field: How Farmers Know What They Know (or Do Not) and Why They Do What They Do (or Do Not)

I arrived at A.'s olive grove to set up a time during which I would be able to work with him and his family during the upcoming annual olive harvest. He operates in the same traditional ways farmers have used for centuries, which means that he does not irrigate the trees but relies on the rainy season to sustain them. He is not familiar with recent discussions on the importance of minimum tilling and leaving dead and live organic matter on the ground to lessen evaporation from the field, suppress weeds, and improve soil health [75]. As A. is already in his 60s and tending to the olive grove is not his main occupation, I was not overly surprised that he was not abreast with recent developments, that is, his sense of place which commands the way he conducts his orchard. I was rather intrigued to see a similar disregard of developments in the field with N., who is in his 30s and manages a mixed farm of cattle and field crops of mainly wheat and barley. He was unaware of recent Ministry of Agriculture initiatives to advance no-tilling farming, which is an agricultural technique for growing crops or pasture without disturbing the

soil through tillage. I asked him about his professional knowledge and how he stays updated, and his answer made it perfectly clear that he does not: "I work with my father who has been working in this plot for the last 20 years. I follow his instructions and I cannot recall going on-line or consulting any of the field guides [a service of the Ministry of Agriculture—author]. I do have a financial consultant who helps me with planning ahead" (interview with author, 11 February 2023).

These two examples do not necessarily represent most of the farmers surveyed. However, they highlight the fact that knowledge in and of itself is not the sole factor leading the farmer's conduct in the field. I will give but one example. While working for L. in his apple orchard I asked him about dead organic cover as the orchard was by and large void of any. To my surprise, he was fully aware of the advantages involved in leaving the organic cover and yet he explained: "I tried it for one year and everything was fine until the workers had to go in and pick the apples. As they start working early in morning, the dew on the vegetation below and between the trees was heavy and turned out to be a problem, as they got wet and kept complaining about it" (interview with author, 18 December 2022). Surely, in this far from exhaustive discussion I am only able to share snippets from the field. However, it brings to the fore the mundane hardships and technical issues that prevent even farmers who take the trouble to be updated from integrating more environmental modes in their field. It is at times the mundane and literally earthy problems at the farm level that ultimately dictate farmers' conduct in the fields. This is Lefebvre's lived space in essence and the ways it is spatialized in the fields. This leads me to an issue that emerged in each of my visits and discussions with farmers: the need to conform to an economically sustainable plan.

3.2. The Political Economy at Farm Level

One of the recurrent themes in all my encounters with farmers was the need to be economically viable and, at the end of the day, to be able to "provide for the family". At the risk of stating the obvious or sounding too naïve, farms and farmers must conform to basic laws of sound fiscal management. E. was a highly sophisticated organic grower who operated a cutting-edge farm intended to export organic products to the American market. However, in 2010, after investing all his savings at the time (circa NIS 500,000), he shut down his operation as the Israeli Ministry of Agriculture failed to provide him with the proper documentation without which he could not get approval to export his goods in the USA. In what follows I deliver his take (almost verbatim) on the political economy, and indeed political ecology, at the farm level:

The persistent calls to encourage "sustainable agriculture" are purely academic and disconnected from the simple albeit crucial fact that agriculture is first and foremost an economic business; on a practical level, farmers could adjust and adopt new methods and practices in the field if at the end of the day they would be able to be profitable. The crucial failing point in sustainable agriculture is that it is simply unprofitable for most farmers; for sustainable agriculture to be profitable, the farmer must acquire the agricultural input at a price that is at least equal to the one received from the conventional chemical alternative. In reaching this goal [more sustainable agriculture] will require not only declarations but also direct financial support and subsidies to the farmers for losses caused by the move to sustainable agriculture (interview with author, 7 July 2022).

His was the most articulate response, which is why it was cited here. It sums up rather clearly the prevailing understanding and conduct among most farmers encountered during this project. And yet, some interlocutors are transforming their farms and embracing new ideas and more sustainable practices (which, in a sense, is a return to preindustrialized agriculture) in the field.

3.3. The Illusive Component in Going Sustainable: Sustainability as Ideology and Suspension of Economical Constraints

As part of the project, farmers (8 in total) who adopted modes of practice that fall under the definition of regenerative agriculture were also interviewed. In general, regenerative agriculture is an alternative means of producing food and operating in farms that aim to have lower environmental and social impacts [76]. This paradigmatic shift from conventional agriculture to a different conceptualization of farming is also discursive. B. is an avocado grower who in recent years has come to the realization that he simply cannot continue with the conventional practice he inherited from the previous manager of the avocado plantation: "I grew up on this land and I live it, and I have realized that many things I do are done automatically, such as the use of preemergence herbicide, … the orchard is part of an ecological tapestry and in order to treat it properly one should disengage from short term economic calculations and think for the long term" (interview with author, 2 January 2023). These insights are exercised daily in his sustainable management of the orchard. The soil, he claims, is not just a matrix for growing avocados but should be treated as a living organism: "We need to nurture it in so it can later feed us. It is a relationship and therefore it is inconceivable to keep on taking forever because it will not last". To that end, he conducts very close monitoring of the amounts of fertilizers used and opts for compost instead of chemical fertilizers. He has eliminated the use of pesticides almost completely. He utilizes cover crops to enrich the soil nutrients and avoids the use of herbicides, which also ensures better absorption of rain and less erosion of the soil during the rainy season. It is part of a transformation in his worldview, as he claims: "It is not an easy process to implement but it is imperative to the existence of a natural ecosystem that exists within the orchard, even if it is a managed commercial one" (interview with author, 2 January 2023). This different attitude and emerging understanding are what I define as the illusive component. Initially, the change in farmers' conduct in the field had nothing to do with integrating professional knowledge, but first and foremost it was a cognitive change, which was later followed by learning new methods.

Indeed, as I was weeding in the baking sun of the Israeli summer in Y.'s wheat field, where he used unmodified seeds (fieldnotes, 1 June 2023), or moving fences with S., a rancher who has adopted Allan Savory's holistic management for cattle (17 March 2023), I could understand the reluctance of many farmers to integrate these methods in the field. It is simply much harder work; it is time consuming and, even more critical at the farm level, it is much more expensive, certainly in the first years of transition from conventional to regenerative cum sustainable agriculture.

This illusive factor is in essence a bold move on the part of the farmer to suspend, if not ignore altogether (certainly in the initial parts of the project), market constraints. In assessing the usefulness of sustainable agriculture as a working concept and framework, Hansen made the distinction between sustainability as an ideology and sustainability as a set of practical practices [77]. The move to a more sustainable mode of production among these farmers was first and foremost an ideological one, which was later transformed into their daily conduct in managing their farms.

That said, while discussing this trend with conventional farmers most of them responded with a mixed bag of skepticism and amusement and doubted the economic sustainability of these methods. As one of them said to me: "I am not sure these sustainable farmers are that sustainable" (interview with author, 6 March 2023). Indeed, in the current climate of Israeli agriculture and against the general lack of support from state agencies, most of the "alternative" farmers I encountered were either backed by a larger corporation they belong to (kibbutzim) or managed to brand themselves and built a strong customers' network that is willing to pay substantially more than market price for their quality products. Theoretically, the integration of sustainable farming should be seen as moving closer to the conceptualized space which involves the intellectualization of space (representations of space in Lefebvre's triad) through the temporary suspension of multiscalar politics and

nested scalar hierarchies above the farm level [37]. These complexities will furnish the last section, as I discuss the horizontal and vertical matrices farmers are engaged with.

3.4. The Local Is Multiscalar Every Step of the Way

T. operates a medium-sized beef cattle farm which he took over from his father. The farm operates as an extensive grazing-based system which means the cows graze freely most of the year within his 10,000 dunums lot, which he leases annually from the state. The basic principle to keep afloat financially, he tells me, is to ensure that each cow delivers one calf a year (interview with author, 12 April 2021). For this to happen he needs to intervene and supply the cows with dry and expensive food when grazing is not enough to revitalize the cows after calving. He also adds poultry manure to their diet as it contains a high ratio of proteins: "If I let the cow recover at a natural pace, it will deliver a calf every two-three year and this is simply not an option for me financially" (interview with author, 12 April 2021).

His main challenges at the farm level are making sure the cows are properly fed and can find water when needed. Additionally, there are many more variables to confront: "In order to have enough biomass for the cows to graze, we need a strong rainy season otherwise I have to bring more food which is very costly. In recent years we have experienced very hot summers, and heat waves greatly affect the cows' health. Here in this region, we also have wolf packs and if one of those land in your ranch, chances are that you lose many calves, as the cows deliver them in the open and there are times, I arrive too late to save them. By the way, I am not allowed to hunt them as they are protected animals" (fieldnotes 11 May 2023).

In addition to the many variables that constantly need to be met at the farm level (horizontal challenges), T. confronts challenges and demands on multiple scales (vertical challenges). The Ministry of Agriculture and the Ministry of Public Health frequently issues new regulations and standards to prevent outbreaks of (new) diseases. Now, no less than 12 kinds of shots are required and surely the costs are paid by the farmers. Other agencies, such as the Ministry of Environmental Protection, restrict his conduct and ensure he operates within strict regulations, for example, to avoid contamination of aquifers or preventing him from hunting possible predators that at times create havoc and devour the young calves. On the national scale he is confronted with fluctuations in the beef prices as dictated by the big merchants and changing customers' habits. In Israel, local beef farms supply circa 8% of the total meat consumed so international import is the most significant player and surely a challenge to local ranchers. Against these horizontal and vertical challenges, T. runs a business that is marginally profitable.

In this short description, a single farm was analyzed while avoiding the "local trap" and bringing a multiscalar analysis into the discussion. This analysis only touches upon some of the challenges at various scales, spatialized at the farm level. It goes well beyond lack of knowledge or indifference to environmental issues that prevent farmers from becoming sustainable. In the current climate, as plainly narrated by T., for most of them it is purely and simply about survival. For significant changes to occur, this situation needs to be acknowledged before any solution may be offered. This will be addressed in the concluding part.

4. Conclusions and Further Reflections

This paper set out to explore Israeli farmers' attitudes and perceptions towards integrating more sustainable modes of agriculture in their farms. It involved a qualitative methodology destined to highlight the challenges, barriers, and "lived space" conceptualization as they are spatialized at the farm level and the ways this informs the management of farms. This is part of the ongoing and lingering debates among scholars and policy makers, which revolves around a key question that was formulated previously in numerous ways: why is it that, despite ample approachable data and existing policies promoting more sustainable modes of productions in the agrifood system, changes among farmers

throughout the globe are very slow to arrive (e.g., Refs. [13,78,79])? The contribution of this paper to this crucial debate is to be found in both theoretical and empirical contexts. The paper offers a theoretical model which explains the complex matrices within which farmers operate while engaging with both horizontal variables (daily conduct at farm level) and vertical factors (multiscalar analysis and scale politics).

The model furnishes my argument that if the debate continues to focus on the farm level and on farmers' conduct in isolation from scalar analysis, changes will be slow to arrive. Empirically, the paper offers a qualitative methodology which enables farmers' voices to be heard which is deemed essential to acknowledge in both scholarly and public debate, and surely for future directions in research and public policies. In adhering to this methodology, I follow Altieri who, while examining farmers' responses to policies forced on them, arrived at the following conclusion: "understanding farmers' existing technology and farming systems is the fundamental step in the design of appropriate development strategies" [28]. Put differently, approaching farmers requires not only technological knowledge but also and probably much more importantly cultural sensitivity and insight into what they perceive as a threat or problem.

Not surprisingly, the project revealed that the fundamental challenge farmers face is mostly the need to comply with today's market economy system. This basic tenet of their work informs their conduct and decision making, at times regardless of their own personal conviction and knowledge. The paper highlights their vulnerability against forces on a multiscalar level which presents numerous challenges in operating their farms. Further, by accepting that scale is relational and in avoiding "the local trap" of scale, the paper suggests that addressing these challenges is essential to enable farmers to integrate more sustainable modes of operation. This would require upscaling the debate and all stakeholders concerned, from the farm level to global players, taking responsibility. Indeed, farming, like any other social–spatialized process cannot be thought of as inherently attached or operating primarily at the farm level.

In addition to the model, it is imperative to stress the need to work closely with farmers and engage in a dialogue with them, instead of explorations of farmers and enforcing regulations and ambitious targets that could never be met without their full cooperation. The specific practices implemented to achieve sustainability are ultimately determined by individual producers. The global need for sustainable agriculture is executed locally as much as the local farm is influenced and effected by the global. If farmers are left more or less on their own to carry out the much-needed integration of sustainable modes of production, while the other links in the agrifood system are conforming to capitalistic logic, it will be rather difficult to affect these much-needed changes [80]. Such relations are typical for the model of economic development implemented since the industrial revolution, where economic growth is reached at the cost of the natural environment [81]. It is apparent that without disconnecting or, as the case may be, allowing temporary suspension from "the capitalist vortex, the maelstrom passing over the earth and sucking up everything in its path" [82], changes at the farm level will remain a utopian and unachievable goal in most cases. Put plainly, for farmers to entertain the move to sustainable cum regenerative agriculture, significant changes are needed in scalar settings far and beyond the individual farm.

As a final conclusion, without a comprehensive consideration of scale the prevailing position among scholars, both intellectually and politically, is likely to continue suggesting that local-scale arrangements, although imperfect, are inherently more liberating and environmentally aware. To avoid this local trap, this paper offers a theoretical resolution that surpasses the local mindset, rather than relying solely on farmers as agents of change against the current economic and political climate. In short, policies need to address the long-term economic viability of farming in all its shapes and forms, simply because farmers do not operate in a neutral environment.

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References

1. Foley, J.A.; DeFries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K.; et al. Global consequences of land use. *Science* **2005**, *309*, 570–574. [CrossRef] [PubMed]
2. Alabi, M.O.; Ngwenyama, O. Food security and disruptions of the global food supply chains during COVID-19: Building smarter food supply chains for post COVID-19 era. *Br. Food J.* **2023**, *125*, 167–185. [CrossRef]
3. Kumareswaran, K.; Jayasinghe, G.Y. Systematic review on ensuring the global food security and COVID-19 pandemic resilient food systems: Towards accomplishing sustainable development goals targets. *Discov. Sustain.* **2022**, *3*, 29. [CrossRef] [PubMed]
4. UN. *Transforming Our World: The 2030 Agenda for Sustainable Development*; UN: New York, NY, USA, 2015; Available online: http://bit.ly/TransformAgendaSDG-pdf (accessed on 11 May 2023).
5. Robertson, M. Measurement and Alienation: Bringing Ecosystems to Market. *Trans. Inst. Br. Geogr.* **2012**, *37*, 386–401. [CrossRef]
6. IPCC. Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. 2019. Available online: https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf (accessed on 20 July 2023).
7. Balogh, M.J. The role of agriculture in climate change: A global perspective. *Int. J. Energy Econ. Policy* **2020**, *10*, 401–408. [CrossRef]
8. Gerber, P.J.; Steinfeld, H.; Henderson, B.; Mottet, A.; Opio, C.; Dijkman, J.; Falcucci, A.; Tempio, G. *Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2013.
9. Hansen, M.C.; Potapov, P.V.; Moore, R.; Hancher, M.; Turubanova, S.A.; Tyukavina, A.; Thau, D.; Stehman, S.V.; Goetz, S.J.; Loveland, T.R.; et al. High-resolution global maps of 21st-century forest cover change. *Science* **2013**, *342*, 850–853. [CrossRef]
10. Parris, K. Impact of agriculture on water pollution in OECD countries: Recent trends and future prospects. *Int. J. Water Resour. Dev.* **2011**, *27*, 33–52. [CrossRef]
11. Rosa, L.; Chiarelli, D.D.; Rulli, M.C.; Dell'Angelo, J.; D'Odorico, P. Global agricultural economic water scarcity. *Sci. Adv.* **2020**, *6*, eaaz6031. [CrossRef]
12. Montgomery, D.R. Soil health and the revolutionary potential of Conservation Agriculture. In *Rethinking Food and Agriculture*; Kassam, A., Kassam, L., Eds.; Woodhead Publishing: Sawston, UK, 2021; pp. 219–229.
13. El Bilali, H.; Strassner, C.; Ben Hassen, T. Sustainable agri-food systems: Environment, economy, society, and policy. *Sustainability* **2021**, *13*, 6260. [CrossRef]
14. Piñeiro, V.; Arias, J.; Dürr, J.; Elverdin, P.; Ibáñez, A.M.; Kinengyere, A.; Opazo, C.M.; Owoo, N.; Page, J.R.; Prager, S.D.; et al. A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nat. Sustain.* **2020**, *3*, 809–820. [CrossRef]
15. Rosário, J.; Madureira, L.; Marques, C.; Silva, R. Understanding farmers' adoption of sustainable agriculture innovations: A systematic literature review. *Agronomy* **2022**, *12*, 2879. [CrossRef]
16. Thompson, B.; Leduc, G.; Manevska-Tasevska, G.; Toma, L.; Hansson, H. Farmers' adoption of ecological practices: A systematic literature map. *J. Agric. Econ.* **2023**, 1–24. [CrossRef]
17. Stoner, A.M. Things are getting worse on our way to catastrophe: Neoliberal environmentalism, repressive desublimation, and the autonomous ecoconsumer. *Crit. Sociol.* **2021**, *47*, 491–506. [CrossRef]
18. United Nations. Food Systems Summit 2021—About the Summit. Available online: https://www.un.org/en/food-systems-summit/about (accessed on 11 May 2023).
19. United Nations. Food Systems Summit 2021—Action Tracks. Available online: https://www.un.org/en/food-systems-summit/action-tracks (accessed on 11 May 2023).
20. Cirella, G.T.; Mwangi, S.W.; Paczoski, A.; Abebe, S.T. Human-nature relations: The unwanted filibuster. In *Sustainable Human–Nature Relations*; Cirella, G., Ed.; Advances in 21st Century Human Settlements; Springer: Singapore, 2020; pp. 3–22.
21. Merrifield, A. Place and Space: A Lefebvrian Reconciliation. *Trans. Br. Inst. Geogr.* **1993**, *18*, 516–531. [CrossRef]
22. Merrifield, A. Henri Lefebvre a Socialist in Space. In *Thinking Space*; Crang, M., Thrift, N., Eds.; Routledge: London, UK, 2000; pp. 167–182.
23. Purcell, M. Excavating Lefebvre: The Right to the City and its Urban Politics of the Inhabitant. *GeoJournal* **2002**, *58*, 99–108. [CrossRef]
24. Yacobi, H. In-Between Surveillance and Spatial Protest: The Production of Space of the 'Mixed City' of Lod? *Surveill. Soc.* **2004**, *2*, 55–77. [CrossRef]
25. Yap, C. New geographical directions for food systems governance research. *Prog. Hum. Geogr.* **2023**, *47*, 66–84. [CrossRef]

26. Pierce, J.; Martin, D.G. Placing Lefebvre. *Antipode* **2015**, *47*, 1279–1299. [CrossRef]
27. Lefebvre, H. *The Production of Space*; Blackwell: Oxford, UK, 1991.
28. Altieri, M.A. Question of small farm development: Who teaches whom? *Agric. Ecosyst. Environ.* **1983**, *9*, 401–405. [CrossRef]
29. Perevolotski, A. Agriculture and Ecology—Can Harmony be Found. In *Perspective on Agroecology from Israel and Abroad*; Volcani Center: Beit Dagan, Israel, 2019.
30. Pretty, J. Intensification for redesigned and sustainable agricultural systems. *Science* **2018**, *362*, 898–904. [CrossRef]
31. Marston, S.A.; Jones, P.J., III; Woodward, K. Human geography without scale. *Trans. Inst. Br. Geogr.* **2005**, *30*, 416–432. [CrossRef]
32. Taylor, P.J. A materialist framework for political geography. *Trans. Inst. Br. Geogr.* **1982**, *7*, 15–34. [CrossRef]
33. Taylor, P. Embedded statism and the social sciences: Opening up to new spaces. *Environ. Plan. A* **1996**, *28*, 1917–1928.
34. Zimmerer, K. Rescaling irrigation in Latin America: The cultural images and political ecology of water resources. *Ecumene* **2000**, *7*, 150–175. [CrossRef]
35. Swyngedouw, E. Neither global nor local: Glocalization and the politics of scale. In *Spaces of Globalization*; Cox, K., Ed.; Guilford Press: New York, NY, USA, 1997; pp. 137–166.
36. Smith, N. Geography, difference, and the politics of scale. In *Postmodernism and the Social Sciences*; Doherty, J., Graham, E., Malek, M., Eds.; Macmillan: London, UK, 1992; pp. 57–79.
37. Wilson, G.A. The spatiality of multifunctional agriculture: A human geography perspective. *Geoforum* **2009**, *40*, 269–280. [CrossRef]
38. Luz, N. The Glocalization of al-Haram al-Sharif. Landscape of Islamic Resurgence and National Revival: Designing Memory, Mystification of Place. In *Islamic Myths and Memories: Mediators of Globalization*; Martensson, U., Weissmann, I., Sedgwick, M., Eds.; Ashgate: London, UK, 2014; pp. 99–120.
39. Mazoyer, M.; Roudart, L. *Histoire des Agricultures du Monde, du Néolithique à la Crise Contemporaine*; Le Seuil: Paris, France, 1997.
40. FAO. International Year of Family Farming. 2014. Available online: http://www.fao.org/family-farming-2014/en (accessed on 20 July 2023).
41. IFAD. International Year of Family Farming: IFAD's Commitment and Call for Action. 2014. Available online: http://www.ifad.org/events/iyff/ (accessed on 18 June 2023).
42. Losch, B. Family farming: At the core of the world's agricultural history. In *Family Farming and the Worlds to Come*; Sourisseau, J.M., Ed.; Springer: Dordrecht, The Netherlands, 2015. [CrossRef]
43. European Commission, Family Farming. 2014. Available online: http://ec.europa.eu/agriculture/family-farming/index_en.htm (accessed on 18 June 2023).
44. Van der Ploeg, J.D. Ten qualities of family farming. *Farming Matters* **2013**, *29*, 8–11.
45. Waldman, K.B.; Giroux, S.A.; Farmer, J.R.; Heaberlin, B.M.; Blekking, J.P.; Todd, P.M. Socioeconomic threats are more salient to farmers than environmental threats. *J. Rural Stud.* **2021**, *86*, 508–517. [CrossRef]
46. Roberts, P. *The End of Food*; Houghton Mifflin Harcourt: Boston, MA, USA, 2009.
47. Evenson, R.E.; Gollin, D. Assessing the impact of the Green Revolution, 1960 to 2000. *Science* **2003**, *300*, 758–762. [CrossRef] [PubMed]
48. Pinstrup-Andersen, P.; Hazell, P.B. The impact of the Green Revolution and prospects for the future. *Food Rev. Int.* **1985**, *1*, 1–25. [CrossRef]
49. Sumberg, J.; Giller, K.E. What is 'conventional' agriculture? *Glob. Food Secur.* **2022**, *32*, 100617. [CrossRef]
50. Moss, D.; Bittman, M. Bringing Farming Back to Nature. *The New York Times*, 26 June 2018. Available online: https://www.nytimes.com/2018/06/26/opinion/farming-organic-nature-movement.html(accessed on 20 June 2023).
51. Tal, A. Making conventional agriculture environmentally friendly: Moving beyond the glorification of organic agriculture and the demonization of conventional agriculture. *Sustainability* **2018**, *10*, 1078. [CrossRef]
52. Paull, J. Attending the first organic agriculture course: Rudolf Steiner's agriculture course at Koberwitz, 1924. *Eur. J. Soc. Sci.* **2011**, *21*, 64–70.
53. Dumont, R. *Types of Rural Economy: Studies in World Agriculture*; Taylor & Francis: Abingdon, UK, 2023.
54. Harris, D.R.; Fuller, D.Q. Agriculture: Definition and overview. In *Encyclopedia of Global Archaeology*; Smith, C., Ed.; Springer: New York, NY, USA, 2014; pp. 104–113.
55. Wezel, A.; Soldat, V. A quantitative and qualitative historical analysis of the scientific discipline of agroecology. *Int. J. Agric. Sustain.* **2009**, *7*, 3–18. [CrossRef]
56. Grosglik, R. *Globalizing Organic: Nationalism, Neoliberalism, and Alternative Food in Israel*; State University of New York Press: New York, NY, USA, 2021.
57. Feitelson, E. Social norms, rationales and policies: Reframing farmland protection in Israel. *J. Rural Stud.* **1999**, *15*, 431–446. [CrossRef]
58. Kliot, N. *Water Resources and Conflict in the Middle East*; Routledge: London, UK, 2004.
59. Hananel, R. Zionism and agricultural land: National narratives, environmental objectives, and land policy in Israel. *Land Use Policy* **2010**, *27*, 1160–1170. [CrossRef]
60. Dekel, T. Mobilization against "agricultural terrorism" and the political-economy of agriculture in Israel. *J. Rural Stud.* **2019**, *72*, 37–44. [CrossRef]

61. Sofer, M.; Applebaum, L. The rural space in Israel in search of renewed identity: The case of the moshav. *J. Rural Stud.* **2006**, *22*, 323–336. [CrossRef]
62. Tal, U. *Agricultural Crime in Israel*; Knesset Center of Research and Information: Jerusalem, Israel, 2007.
63. Golan, P. How did the Arava Become the "Silicon Valley" of Israeli Agriculture? *The Jerusalem Post*. 10 March 2023. Available online: https://www.jpost.com/business-and-innovation/energy-and-infrastructure/article-733810#:~:text=The%20central%20Arava\T1\textquoterights%20600%20agricultural,rainfall%20of%20only%20two%20inches (accessed on 16 June 2023).
64. Fanos, D. *The Agricultural Sector in Israel: Economic Status 2016*; Ministry of Agriculture and Rural Development: Jerusalem, Israel, 2017.
65. Temper, L. Creating facts on the ground: Agriculture in Israel and Palestine (1882–2000). *Hist. Agrar. Rev. Agric. Hist. Rural* **2009**, *48*, 75–110.
66. Reimer, A.; Doll, J.E.; Boring, T.J.; Zimnicki, T. Scaling up conservation agriculture: An exploration of challenges and opportunities through a stakeholder engagement process. *J. Environ. Qual.* **2023**, *52*, 465–475. [CrossRef]
67. Šūmane, S.; Kunda, I.; Knickel, K.; Strauss, A.; Tisenkopfs, T.; des Ios, I.; Rivera, M.; Chebach, T.; Ashkenazy, A. Integration of knowledge for sustainable agriculture: Why local farmer knowledge matters. In Proceedings of the 12th European IFSA Symposium Conference Proceedings, Shropshire, UK, 12–16 July 2016; Wilcox, A., Mills, K., Eds.; Harper Adams University: Shropshire, UK, 2016; Volume 1, pp. 614–629.
68. Bradley, D.; Hill, B.; O'Prey, L.; Griffiths, E.; Williams, E. Understanding Farmer Motivations: Very Small and Small Farms. IHS Markit; 2021. Available online: https://www.gov.wales/understanding-farmer-motivations-very-small-and-small-farms (accessed on 20 July 2023).
69. Chebach, T.C.; Ashkenazy, A.; Tchetchik, A.; Blass, V. What makes farmers follow the standard? The role of regional characteristics, local alternatives, and policy support in non-state market driven governance in the Arava, Israel. *Geogr. Res. Forum* **2022**, *41*, 117–151.
70. Agnew, J. The territorial trap: The geographical assumptions of international relations theory. *Rev. Int. Political Econ.* **1994**, *1*, 53–80. [CrossRef]
71. Brenner, N. The limits to scale? Methodological reflections on scalar. *Prog. Hum. Geogr.* **2001**, *25*, 591–614. [CrossRef]
72. Agnew, J. The dramaturgy of horizons: Geographical scale in the Reconstruction of Italy by the new Italian political parties, 1992–1995. *Political Geogr.* **1997**, *16*, 99–121. [CrossRef]
73. Kelly, P. The geographies and politics of globalization. *Prog. Hum. Geogr.* **1999**, *23*, 379–400. [CrossRef]
74. Brown, J.C.; Purcell, M. There's nothing inherent about scale: Political ecology, the local trap, and the politics of development in the Brazilian Amazon. *Geoforum* **2005**, *36*, 607–624. [CrossRef]
75. Parvaze, S.; Kumar, R. Organic wastes in agriculture: Risks and remedies for sustainable agriculture production. *Contam. Agric. Environ. Health Risks Remediat.* **2019**, *1*, 21.
76. Newton, P.; Civita, N.; Frankel-Goldwater, L.; Bartel, K.; Johns, C. What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. *Front. Sustain. Food Syst.* **2020**, *4*, 194. [CrossRef]
77. Hansen, J.W. Is agricultural sustainability a useful concept? *Agric. Syst.* **1996**, *51*, 185–201. [CrossRef]
78. Amede, T.; Konde, A.A.; Muhinda, J.J.; Bigirwa, G. Sustainable farming in practice: Building resilient and profitable smallholder agricultural systems in sub-Saharan Africa. *Sustainability* **2023**, *15*, 5731. [CrossRef]
79. Fujisaka, S. Learning from six reasons why farmers do not adopt innovations intended to improve sustainability of upland agriculture. *Agric. Syst.* **1994**, *46*, 409–425. [CrossRef]
80. van Vliet, J.A.; Schut, A.G.; Reidsma, P.; Descheemaeker, K.; Slingerland, M.; van de Ven, G.W.; Giller, K.E. De-mystifying family farming: Features, diversity and trends across the globe. *Glob. Food Secur.* **2015**, *5*, 11–18. [CrossRef]
81. Sulewski, P.; Kłoczko-Gajewska, A.; Sroka, W. Relations between agri-environmental, economic and social dimensions of farms' sustainability. *Sustainability* **2018**, *10*, 4629. [CrossRef]
82. Walker, R.; Moore, J.W. Value, nature, and the vortex of accumulation. In *Urban Political Ecology in the Anthropo-Obscene*; Ernstson, H., Swyngedouw, E., Eds.; Routledge: London, UK, 2018; pp. 48–68.

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Does Intra-Urban Residential Relocation Affect the Elderly's Health and Well-Being? An Empirical Study of Nanjing, China

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Abstract: There are few existing studies from a spatial perspective that explore the mechanism of the living environment, relocated direction and relocated distance on the elderly's physical and mental health. Based on the 2019 household survey questionnaire data, this study utilizes a binomial logistic regression model and residents' in-depth interviews to study relocated behavior in Nanjing. We analyzed the spatial–temporal characteristics of relocated behaviors, the accumulation effect at different stages and the influence of relocated intention on physical and mental health among the elderly. The findings are as follows: (1) The mode of relocation among the elderly includes long-term cumulative effects and short-term effects. Frequent relocation has a cumulative negative impact on the physical and mental health of the elderly. (2) The elderly relocated in the short-term had a great negative impact on their mental health but had no significant impact on their physical health. (3) In the last relocation, active relocation had a significantly positive impact on physical health. The "centrifugal relocation" from the main urban area to the surrounding new cities has a significant positive impact on mental health. Moreover, long-distance relocations adversely affected mental health.

Keywords: binomial logistic regression; residential relocation; physical health; well-being; Nanjing

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1. Introduction

Relocation, or intra-urban residential relocation, is the housing adjustment process carried out by residents due to the mismatch between housing supply and demand [1]. Relocation is one of the important driving forces for urban spatial reconstruction [2]. Intra-urban residential relocation is an important factor that affects the evolution of urban morphology [2]. Residents move and regroup within the city, indirectly changing the urban spatial patterns [3]. Existing research divided relocation behavior into three aspects based on the process of relocation: the motivation, the process and the impact of residential migration [4], as shown in Figure 1.

Many experts in the field of urban science deeply explore the internal relationship between relocation and residents' daily lives from the perspective of residents [5]. It mainly includes four aspects. The first is how the researchers have conducted in-depth research on the transport travel mode of residents, including a low-carbon travel mode, transport travel choice, shopping, leisure travel mode, etc. [6]. The second is the perspective of the relationship between commuting behavior and built environment, such as the relationship between work and residence, and the correlation between commuting behavior and social networks [7]. The third is the indirect impact of residents' social attributes on their health,

including social differentiation, neighborhood environmental characteristics, urban built environments and residents' health relations [8,9]. The last is the relationship between residents' subjective psychological perception and health, including the subjective well-being of migrants, the elderly mortality and incidence rate, adolescent problem behaviors and the correlation between residents' physical and mental health [10].

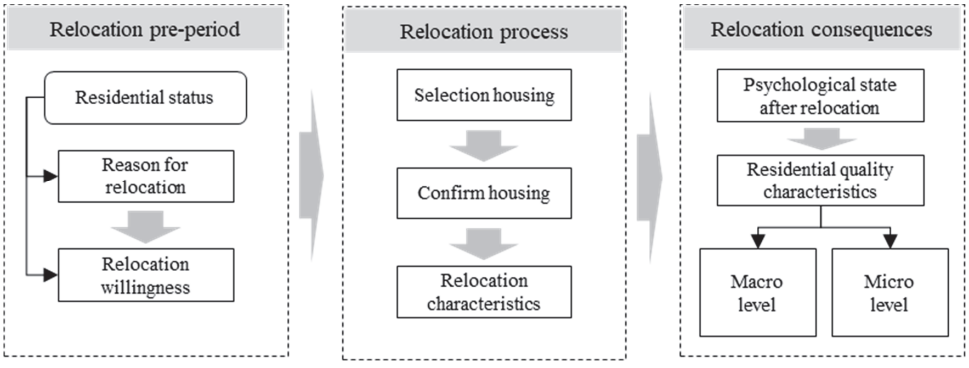


Figure 1. The regulatory and influencing factors on relocation behavior.

Relocation has been found to have an impact on the urban spatial structure, thereby affecting the residents' health [11]. The changes in urban spatial structure will change the key areas of urban development, leading to the phenomenon of urban spatial differentiation [12]. The differentiation of living space leads to the differentiation of individual socioeconomic status, neighborhood physical environment and social environment, which has indirectly effect on health [13,14]. The social environment in the neighborhood has a particularly important impact on health, especially in terms of "perception or satisfaction with the living environment" and "accessibility of social network resources" [15]. Relocation is an important factor that leads to the differentiation of urban social spatial structure and changes in individual behavior. Research can reflect the health impact of urban spatial structure differentiation by measuring the impact of relocation on health [16]. The relevant research originated from the behavior that a large number of the elderly moved to a community containing public medical resource gathering under the background of "deinstitutionalisation". Existing studies have primarily focused on the following. The first is the impact of relocation on mortality, incidence rate and physical and mental health indicators [17]. The findings show that relocation has short- and long-term cumulative effects on the elderly's health, but the impact mode is still unclear [18]. Some studies have found that relocation may lead to weight loss among the elderly, decreased mobility and negative psychological emotions [19,20]. Frequent relocation experiences may result in mental illness and out-of-going behavior disorders in the elderly [21,22]. However, if the elderly move to an area with better-built environment conditions, it may result in a stronger sense of happiness [23]. The second factor is the adjustment factor of the relocation's influence on health. The effect of relocation on health is affected by many factors, such as individual socio-economic attributes, social support, neighborhood relations and living habits [24–27]. This type of research mainly analyzes the regulatory effects of various variables through quantitative models, compares the differences between the groups affected and summarizes the mechanism of relocation on residents' health.

With the development of relevant theories of social psychology, some scholars began to study the impact of migration behavior on the subjective well-being of elderly individuals, and then expanded to the physical and mental health of the whole age group [28–30]. Some theoretical models provide a research framework for studying the health effects of residential relocation, including social capital theory and social ecology theory. Social capital theory refers to the social interpersonal relationships and social networks established within

the social ecosystem [28]. The social system constructed by relatives, important friends and neighbors in residential communities is an important social support environment for individuals. Social capital has a crucial impact on an individual's development goals, cognitive abilities and social interaction abilities. Some studies suggest that residential migration can disrupt this individual social network and cause social dysfunction [29]. Social capital is closely related to the relationships between individuals within and outside the family, while residential migration weakens the relationships within the family, between families and between neighbors, thereby affecting residents' mental health and subjective well-being [30]. Social ecological theory is a theory that studies the relationship between humans and various social environmental factors [31]. When studying health levels and health behaviors, social ecology theory requires analyzing relevant phenomena from the perspective of the interaction between humans and the environment [31]. Healthy behavior is an element within a complex system of people and the environment. The other elements within the system include: (1) internal factors, such as knowledge, attitude, behavior, self-concept and skills; (2) interpersonal relationships, social networks and support systems, such as family members, friends and colleagues; (3) group factors, including formal and informal social groups; (4) community factors, including the environment and related work conditions of the community; and (5) public policies, including various relevant laws and policies [32]. Scholars believe that the relocation behavior that affects health includes several important factors such as controllability, personal socio-economic attributes, important events in life processes and relocation willingness [32], as shown in Figure 2.

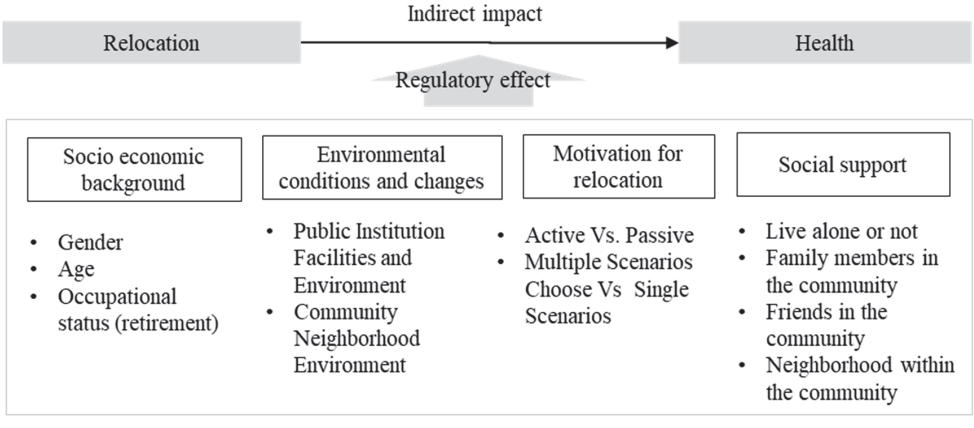


Figure 2. The stages and specific factors that affect the relationship between relocation and health.

Most of the existing research focuses on the field of medicine and psychology, targeting relocation behavior as a result [33]. The existing research lacks an in-depth analysis of the spatiotemporal characteristics and specific processes of relocation behavior [34]. Sociology refers to environmental variables related to health as contextual variables [35]. The different transportation environments in which residents live determine different situational variables and environmental experiences, thereby affecting their health [35]. Therefore, the perspective of temporal and spatial behavior is a new research trend in health geography [36]. Scholars have classified residents' daily activities into long-term behaviors such as employment and residential migration and short-term behaviors such as commuting and shopping. Relevant research should classify daily activities based on cyclical characteristics [37]. Relocation, as a long-term behavior of residents' daily activities, determines environmental variables closely related to residents' health [38]. Therefore, it is necessary to study the health effects of relocation from the perspective of spatiotemporal characteristics and explore the role and mechanism of the spatiotemporal characteristics of relocation in the influencing factors of residents' health. Furthermore, the existing research

lacks a comparative analysis of the residents' health before and after relocation and focuses on the changes in objective variables such as whether residents move and the relocation frequency. In terms of health effects, existing studies have mainly used the stress and coping theory and the moving to opportunity perspective for reference to deeply analyze the indirect impact of environmental changes on residents' physical and mental health [39]. Existing studies have given more attention to changes in residents' health indicators and less attention to the systematic impact mechanism of residents' relocation behavior patterns on health [40]. Moreover, the social capital theory posits that changes in social networks harm residents' mental health [41,42].

Currently, China is now in a stage of rapid urbanization and population ageing. In 2019, the urban population of China was 914.25 million, an increase of approximately 200 million compared to 10 years ago. The urbanization rate of the permanent population has increased from 37.6% to 63.5%. According to United Nations standards, when the elderly aged 65 and above account for 7% of the total population, the region can be considered as entering an aging society [43]. In 2019, the number of elderly people aged 65 and above in China reached over 200 million, accounting for 14.2% of the total population. China has entered a stage of deep aging society. The relocation activities of residents in large cities in China occur frequently, and most of them occur in urban built-up areas [44]. This study selected Nanjing, China, as a case study, analyzed the temporal and spatial characteristics of residents' relocation activities and explored the cumulative and short-term effects of relocation behavior and residents' health. We obtained residents' behavior data based on a questionnaire survey, and quantitatively measure residents' relocation from three aspects: migration frequency, migration period and migration characteristics. The overall research framework is shown in Figure 3. Firstly, this article measures the long-term cumulative impact of elderly population relocation frequency indicators on residents' health levels. Secondly, this article measures the changes in the health level of the elderly population before and after their relocation in the short term. Thirdly, this article measures the impact mechanism of specific relocation on the health level of the elderly population from three aspects: subjective migration willingness, objective migration distance and objective migration direction. Specifically, this study quantitatively analyzed the impact of relocation distance, intention and direction on residents' physical and mental health. Factors such as individual socio-economic attributes, living habits, neighborhood environment and social support were included in the model as control variables to analyze the process mediation and indirect impact of socio-economic variables on relocation activities. Based on social ecology theory, this study analyzes the effect of relocation on individual health through a quantitative mathematical model. The research results can provide a useful reference for individual residential choices and urban community construction.

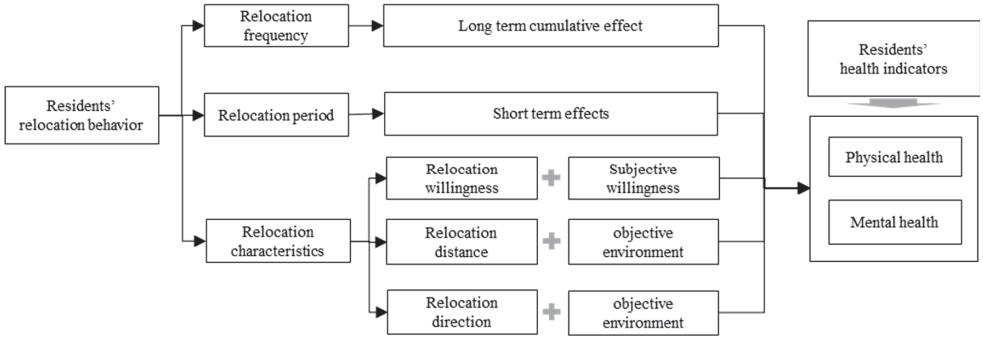


Figure 3. The overall framework of the relocation behavior effect on residents' health.

2. Data and Methods

2.1. Data Collection

Nanjing was selected for the case study. Nanjing is the capital city of Jiangsu Province, with a total land area of 6587.1 square kilometers and an urban built-up area of 868.3 square kilometers. In 2019, Nanjing had jurisdiction over 11 municipal districts, 94 streets and six towns. In 2019, the total population of Nanjing was 9.282 million, the urban population was 8.066 million and the urbanization rate reached 86.9%. The urban built-up area of Nanjing presents a "circle" spatial pattern. The inner old city covers an area of 172.3 square kilometers, including some streets in Gulou District, Qinhuai District, Xuanwu District and so on. The population distribution in the old urban area of Nanjing is dense, and the city is in the late stage of urbanization transformation and development. The main urban area around the old city covers an area of 372.8 square kilometers, including the Jianye District, Qixia District, Yuhuatai District and other streets. The outer new urban area covers an area of 323.2 square kilometers, including the Jiangbei New Area, Jiangning District and other streets.

This study selected the old urban area of Nanjing, the main urban area between the inner ring road and ring expressway and the area outside the ring expressway as the study area [45]. The study area included the Xuanwu, Qinhuai, Jianye, Gulou, Pukou, Qixia, Jiangning and Jiangning Districts. We select Nanjing as a representative case site, which includes two aspects. Firstly, the proportion of elderly people in Nanjing is relatively high. In 2019, there were 1.8246 million permanent elderly residents aged 60 and above in Nanjing, accounting for 19.36% of the total population [46]. Secondly, the relocation proportion of elderly people in Nanjing is relatively high. In the past 5 years, the demolition proportion of old communities in the main urban area of Nanjing has increased to 32.5%. The elderly population mainly lives in old communities in the main urban area. Due to large-scale demolition, the elderly need to choose a new residence place, leading to relocation behavior. Overall, 21 typical blocks were selected from eight administrative regions for the questionnaire survey (Figure 4). "Block" refers to a relatively independent land parcel with an area of about 1 square kilometer enclosed by surrounding roads. The blocks selected in this study included five types, namely historical blocks, unit communities, commercial housing blocks, affordable housing blocks and self-built houses (Table 1).

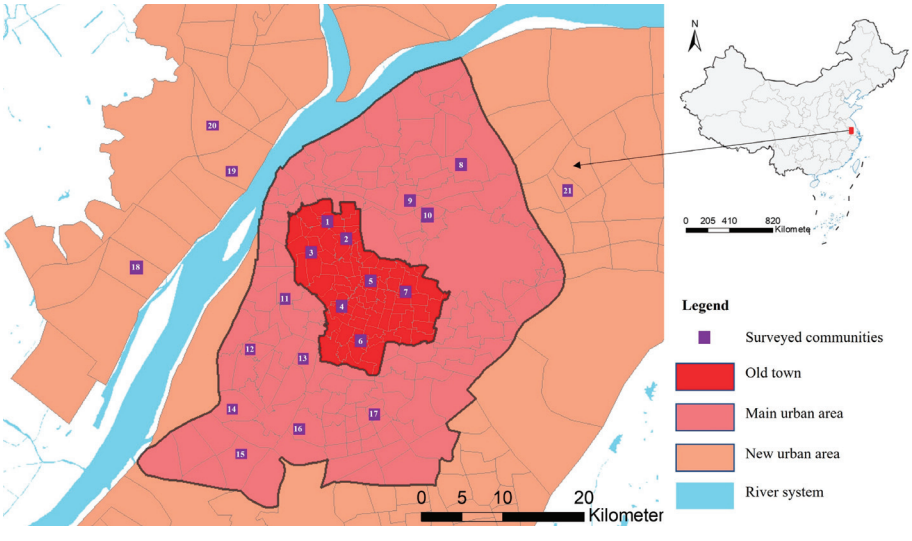


Figure 4. Distribution of the surveyed communities.

Table 1. Basic information of the investigated block.

Block		Street	Main Information
Old Town	Xuanwumen block	Historic block	Residents built their own houses in the 1970s
	Suojincun block	Historic block	Residents built their own houses in the 1970s
	Maigaoqiao1 block	Historic block	Government buildings in the 1970s
	Meiyuanxincun block	Public housing block	Government buildings in the 1970s
	Honghua block	Public housing block	Residents built their own houses in the 1970s
Main urban area	Honghulu block	Commercial housing block	New commercial housing built after 2000
	Wulaocun block	Commercial housing block	New commercial housing built and resettlement housing after 2000
	Yueyahu block	Public housing block	Housing owned by government agencies
	Zhonghuamen block	Historic block	Residents built their own houses in the 1980s
	Guanghualu block	Indemnificatory housing block	Affordable housing after the 1980s
	Dingshan block	Indemnificatory housing block	Affordable housing after the 1980s
New urban area	Dachang block	Public Community	Housing owned by government agencies
	Xianlin block	Commercial housing block	New commercial housing built and resettlement housing after 2000
	Yanziji block	Commercial housing block	Commercial housing constructed after 2000
	Yaohua block	Commercial housing block	Commercial housing constructed after 2000

In January 2019, we conducted a questionnaire survey on the effects of relocation and the health of urban residents. According to the relevant provisions of the Chinese Law on the Protection of the Rights and Interests of the Elderly, the elderly generally refers to people over the age of 60 [43]. The elderly people we surveyed are permanent residents who have no major illnesses, are easy to move and are able to independently complete the questionnaire. We distributed a total of 1272 questionnaires and ultimately obtained 1063 valid questionnaires, with an effective response rate of 85.05%. The 1063 valid questionnaires have the proportion of men and women as 49.95:50.05.

The questionnaire passed the reliability test, with a coefficient α of 0.75 and acceptable reliability. From the basic situation of the elderly sample (Table 2), the proportion of unmarried and married samples was 21.73:78.27, with an average age of 62.05. The average monthly income of individuals is CNY 2000–4000. The majority of households have a population of three or less (55.16%). Approximately 78.2% of the populations have a self-rated health level of normal or above. The objective built environment element data include urban public service facility point of interest (POI) data, administrative boundaries at all levels of the city, etc. Among them, POI data are obtained through online maps, with attributes including the names, categories, longitudes and latitudes of various spatial entities. At the same time, we obtained the information about the residential location and daily activity trajectory of the elderly through a questionnaire survey and matched them in geographical space.

Table 2. Descriptive information on the sample of the elderly in the study (N = 1.063).

Item	Count	Proportion	Item	Count	Proportion	Item	Count	Proportion	
Gender			Marital status			Self-rating physical mental status			
Male	531	49.95	unmarried	231	21.72	Very good	67	6.32	
Female	532	50.05	married	832	78.27	Good	417	39.27	
Age			Household Size			Normal	459		43.23
60–70	673	62.32	<3	586	55.16				
71–80	247	23.24	3–5	359	33.77	Not good	120	11.18	
>80	143	14.44	>5	118	11.07				
Education level			Monthly individual income			Self-rating physical health status			
Primary school and below	379	35.69	<2000	183	17.18	Very good	120		11.37
Junior high school	518	48.71	2000–4000	652	61.30	Good	454	42.75	
High school and above	166	15.61	>4000	228	21.49	Normal	272	25.63	
						Not good	75	20.25	

Note: The proportion unit is %.

We conducted a survey on the physical and mental health of residents in the questionnaire, as shown in Table 3. Among them, physical condition indicators include self-assessment of physical health index, frequency of physical discomfort and frequency of severe physical pain; mental health indicators include self-rated mental health index, frequency of self-rated low emotional state and self-rated level of life satisfaction. These questionnaire options can further refine and quantify the evaluation of residents' physical and mental health levels.

Table 3. Explanatory variables of residential relocation.

Analysis Dimension	Specific Indicators	Indicator Description
Cumulative effect	Relocation frequency	We took the frequency of the respondents' relocation after they settled in Nanjing as an explanatory variable. This variable expresses the cumulative effect of relocation behavior on residents' health.
Short-term effects	Relocation period	This indicator is utilized to determine whether the length of relocation has a differential impact on health status.
Relocation characteristics	Relocation Willingness	The indicators are divided into active relocation and passive relocation.
	Relocation direction	We define Gulou District and Qinhuai District as the old urban area, and the peripheral areas include the main urban area and the new urban area. We subdivide the relocation direction into four directions: interior–interior, interior–exterior, exterior–interior and interior–exterior. It has been pointed out that the orientation of relocation is related to the change in the living environment [47].
	Relocation distance	We make spatial matching for the residential areas before and after the relocation and further calculate the relocation distance. Long-distance relocation is generally considered to be related to social network faults and environmental change [48].

2.2. Indicator System

The relocation behavior studied in this paper mainly refers to intra-city relocation between streets in Nanjing, focusing on the supply of medical institutions and other public services around the elderly relocation site. Few studies have linked the spatial characteristics of relocation to health effects [32,35,40]. This paper presents a multi-dimensional analysis of the spatiotemporal characteristics of relocation, specifically relating the relocation direction, relocation distance and residents' health effects. The indicators of relocation were employed to measure the actual health effects and mechanisms. Based on the existing research findings, we believe that relocation can be measured from multiple dimensions, such as relocation frequency, duration, direction, distance and intention (Table 3). The frequency of relocation reflects the cumulative effect of relocation [49,50], and the length of residence after relocation signifies the short-term effect of relocation [51]. The willingness to relocate is also a crucial factor affecting residents' health [52]. These indicators are important explanatory variables for the impact of relocation on health.

The health measurement standards of the residents are listed in the following table (Table 4). Residents' physical health (self-rated physical health) and mental health (self-rated mental health) are the two main dimensions for measuring health. The World Health Organization believes that health refers to a good state of physical, psychological and social adaptation [48,52] and includes four aspects. The first is to be energetic, and residents can calmly cope with daily life and work. The second is emotional stability, positive attitude and maintaining optimism when facing difficulties. The third is to be good at rest and have good sleep quality. The fourth is that residents have a strong ability to cope with changes in the external environment. We measured the influence of relocation on the daily lives of the elderly through physiological and psychological indicators. Self-assessment of physical health is one of the most commonly employed indicators in residents' health research and is usually measured in the form of grading [53,54]. The physical discomfort index expresses a situation wherein residents' physical discomfort affects their work efficiency. The physical pain index expresses the frequency of physical pain in

residents within 1 month. Self-assessment of mental health mainly adopts the mental health assessment scale recognized by the World Health Organization (WHO) [55]. Psychological depression corresponds to physical discomfort, reflecting the negative emotions that affect residents' daily life and work status. Life satisfaction is also commonly used as a measure of mental health and is generally divided into six levels [54]. Depression is the most common psychological disorder, which refers to a continuous and long-term state of depression in patients [55]. People with depression have a low mood, unhappy life and prolonged depression. Patients may experience a decrease in self-evaluation, resulting in feelings of helplessness, hopelessness, helplessness and worthlessness. Patients often experience self-blame and self-guilt, and in severe cases, symptoms of delusions of guilt and hypochondriasis may occur [54]. Accordingly, this study classifies the mental health level into two categories and constructs a logistic regression analysis model. A value below 13 indicates poor mental health, whereas a value higher than 13 indicates good mental health. Moreover, life satisfaction is a critical indicator of residents' mental health [56], which is mainly divided into five grades.

Table 4. Measurement indicators of physical and mental health.

	Indicators	Questions	Scoring Rules
Physical health	Physical Health Score	"Please evaluate your physical health"	1 = very poor; 2 = poor; 3 = average; 4 = good; 5 = very good
	Physical discomfort	"In the past month, did you feel unwell and found these problems affecting your work or other daily activities?"	1 = no; 2 = rarely; 3 = sometimes; 4 = often; 5 = always
	Severe pain	"Did you experience severe pain in the past month?"	1 = no; 2 = rarely; 3 = sometimes; 4 = often; 5 = always
Mental health	Mental Health Score	Item 1: "I feel happy" Item 2: "I feel calm and relaxed" Item 3: "I feel energetic" Item 4: "I feel my body recovered after I wake up" Item 5: "My life is full of interesting things every day"	The general Likert scale for mental health used by WHO was utilized for scoring [55]. There were five questions in total, and six items (0–5 points) represented the degree of agreement with the item description in the past two weeks; 0–25 points in total
	Emotional problems	"In the past month, did you feel depressed or anxious, and did these problems affect your work or other daily activities?"	1 = no; 2 = rarely; 3 = sometimes; 4 = often; 5 = always
	Life satisfaction	"Are you satisfied with your quality of life?"	1 = very dissatisfied; 2 = dissatisfied; 3 = average; 4 = relatively satisfied; 5 = very satisfied

2.3. Research Methods

In this study, the frequency, duration, distance, willingness and other indicators of relocation were employed as explanatory variables to measure the impact of relocation on residents' health. It has been considered that personal socio-economic attributes and personal living habits have an impact on residents' relocation and physical and mental health. Among them, social support mainly plays a role in mental health, whereas hardware facilities (e.g., medical support) are primarily involved in physical health [47,49,57]. Therefore, we used these measures as the control variables. SPSS 22.0 software was employed to measure the direction and intensity of the relocation effects on health. Logistic regression models are frequently utilized in epidemiological studies. Specifically, logistic regression analysis results included the following indicators: partial regression coefficient B, standard error (SE), Wald chi-square test value, *p*-value and odds ratio (OR) value ($\exp\beta$) and 95% confidence interval (CI) value of OR value. In the field of epidemiology and public health, the OR is usually used to measure the specific factors influencing health effects. The OR value refers to the ratio of the event occurrence rate to the non-occurrence rate. When the OR value is significant at a significance level of 0.05, the OR value is also used as a dose indicator. If OR < 1, this factor is negatively related to the health level and has a protective effect on disease prevention. If OR > 1, this factor is positively correlated with health levels [56,58]. Therefore, OR and 95% CI were the key indicators in the logistic

model. This indicator was employed to test the effect of the direction and intensity of the relocation process on health.

The effects of relocation on health can be accumulated and are related to residents' life stages. Relocation in different periods has different impacts on residents' health. To verify this cumulative effect, the residents' relocation experience was divided into three stages: nearly 1 year, nearly 3 years and nearly 5 years. Binomial logistic regression analysis is a multivariate analysis method used to study the relationship between relocation behavior and explanatory variables. This method is mostly utilized in medical sociology and public health research and can comprehensively test the factors influencing health risk [43]. Generally, there are two classification results of health prediction: healthy and unhealthy. The research assumptions in this study were consistent with the conditions of the binomial logistic model. The dependent variable Y of the model obeys a binomial distribution, and its binomial classification value is either 0 or 1. The overall probability of $Y = 1$ is $\pi(Y = 1)$ and the logistic regression model corresponding to m independent variables x_1, x_2, …, x_m is as follows:

$$\pi(Y = 1) = \frac{\exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_m x_m)}{1 + \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_m x_m)} = \frac{1}{1 + \exp[-(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_m x_m)]}$$

where, x_1, x_2, …, x_m are the driving factors affecting health-related variables. β_0 is the intercept (or constant term) and β_j is the regression coefficient to be calculated corresponding to x_j (j = 1, 2, …, m). If the value is positive (negative), the relevant independent variable $x_{j,i}$ can increase (decrease) the occurrence rate of event i. The higher the absolute value of β_j, the greater the influence of the independent variable $x_{j,i}$ on the occurrence rate of event i. $\exp(.)$ is an exponent based on the natural logarithm [42].

The fitting effect of the model was further evaluated. We used a sample of residents in good health as the reference group. The independent variables of the model were selected via the entry method. The model estimation results are presented in the following table (Table 5). Among them, pseudo R^2 values were 0.186 and 0.175, respectively, meeting the needs of social investigation. According to the Hosmer–Lem show test index, X^2 of the model is 4.938 and 9.468, respectively, and the p values are 0.764 and 0.304, respectively. Therefore, we cannot reject the hypothesis of a good fit and the model results can be accepted. The accuracy rates for physical and mental health were 76.6% and 70.1%, respectively, highlighting that the fitting effect of the model was good.

Table 5. Fitting test of relocation cumulative effect model on health.

Model Summary	−2 Log-likelihood	Cox and Snell R^2	Nagelkerke R^2
Model I (physiological health)	1009.579	0.186	0.268
Model II (mental health)	1160.088a	0.175	0.239
Hosmer–Leme show test	X^2	df	Significance
Model I (physiological health)	4.938	8	0.764
Model II (mental health)	9.468	8	0.304

3. Results

3.1. General Characteristics of Residents' Relocation and Health

3.1.1. Temporal and Spatial Characteristics of Relocation Activities

We performed statistics on the relocation frequency of residents in Nanjing, and the relocation frequency of most residents was 1–2 times. Residents who had moved more than once accounted for 75.7% of the total respondents. Specifically, this notion outlines that the resident changed his/her residence after entering Nanjing. The frequency of relocation of residents in Nanjing is generally increasing in terms of the characteristics of the different stages. After 2000, the relocation frequency increased significantly, with an annual relocation rate of 26.8%. In the 21st century, the average annual relocation rate of Nanjing residents was 35.6%. This value is generally consistent with the relocation rate of

urban residents at the same developmental stage reported in previous studies [57]. From the perspective of relocation distance, the spatial characteristics of the elderly in Nanjing conformed to the law of distance attenuation (Figure 5). Among them, the elderly within 5–10 km accounted for the highest frequency of relocation. The frequency of relocation within 10 km accounted for more than 60%, that above 20 km accounted for only 5.20% and that within 10–20 km accounted for 30.89%.

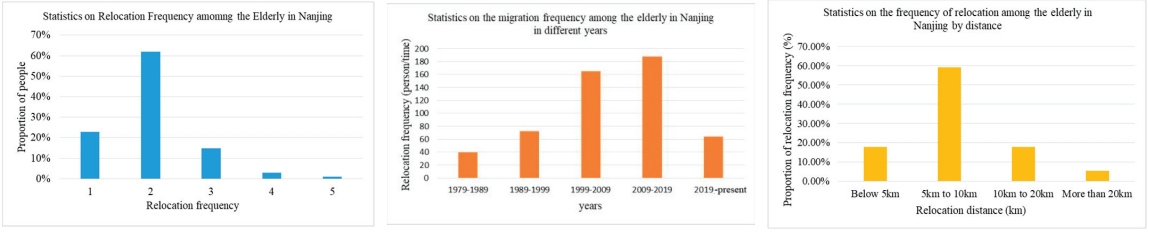


Figure 5. Statistics of Nanjing residents' relocation frequency (**left**), statistics of Nanjing residents' relocation frequency by time period (**middle**) and characteristics of Nanjing residents' relocation distance (**right**).

We collated and analyzed 1388 relocation samples from Nanjing and acquired 976 records of relocation activities. Thereafter, the spatial location of the residence before and after the relocation was connected, and the relocation path of the residents was obtained (Figure 6). In general, relocation mainly shows the "centrifugal" spatial characteristics of the old city to the new city. There are intensive short-distance relocation activities in the main urban area, whereas there are few short-distance relocation activities in the surrounding new urban area.

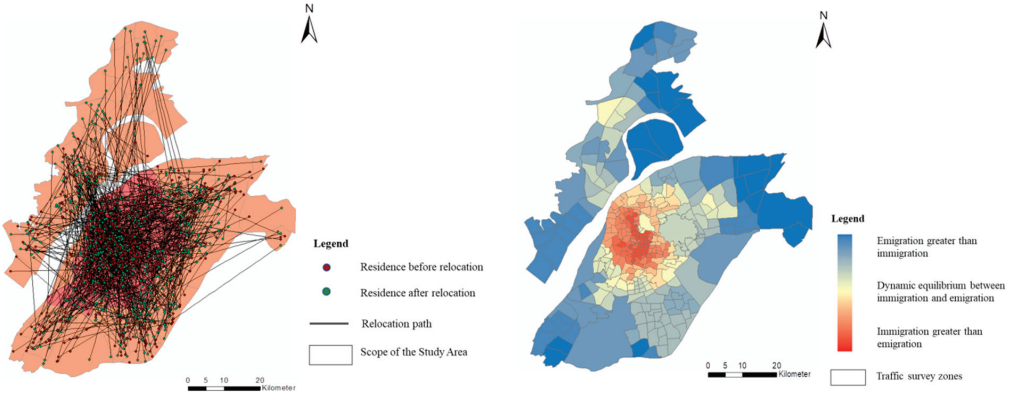


Figure 6. Relocation path (**a**) and quantity (**b**) among the elderly in Nanjing.

We defined the Jiangbei New Area and Jiangning District as new urban areas and defined other areas as main urban areas or old urban areas to obtain the characteristics of residents' relocation direction (Table 6). According to the statistics of administrative districts, the outcomes show that the distribution of residents' locations of relocation is relatively average, and the districts with more relocation are Pukou District, Jiangning District and Qixia District. The relocation areas of residents were mainly concentrated in the Jianye District (35.27%) and Gulou District (21.20%). From the perspective of the spatial pattern of relocation activities, the relocation rate from the peripheral area to the main urban area was relatively high (accounting for approximately 63.21%), while the proportion

of relocation from the main urban area was only 13.83%. Second, short-distance relocation in the old urban area accounted for 15.90%. The proportion of people moving from the old city to peripheral areas was the lowest, accounting for 9.38%. Gulou District accounts for 10.7% of the internal relocation activities in the main urban area, and the Jiangning and Qixia districts account for 7.14% and 6.32%, respectively.

Table 6. Statistics of the residents' imrelocation and erelocation places among the elderly in Nanjing.

Move In and Out	Xuanwu District	Qinhuai District	Jianye District	Gulou District	Pukou District	Qixia District	Jiangning District	Total	Old City	Peripheral Area
Xuanwu District	2.45%	1.43%	3.06%	/	1.22%	5.10%	1.33%	14.58%		
Qinhuai District	0.10%	0.31%	0.10%	/	/	0.51%	/	1.02%		
Jianye District	0.92%	2.24%	6.32%	/	0.51%	5.81%	2.96%	18.76%		
Gulou District	/	/	0.51%	/	0.20%	0.51%	0.10%	1.33%		
Pukou District	1.94%	2.65%	4.89%	/	3.77%	4.28%	3.36%	20.90%	/	/
Qixia District	0.51%	0.61%	2.34%	0.10%	1.43%	10.70%	1.53%	17.23%		
Jiangning District	2.14%	2.85%	3.87%	/	1.63%	8.26%	7.14%	25.89%		
Total	8.05%	10.09%	21.20%	0.10%	8.87%	35.27%	16.41%	100%		
Old city				/					15.90%	9.38%
Peripheral area				/					30.89%	43.83%

3.1.2. Health Characteristics of the Elderly Migrants

We conducted a cross-tabulation analysis between relocation attributes and the health status of the elderly (Table 7). According to the model results, when controlling for the influencing factors of individual socio-economic attributes, lifestyle habits and neighborhood social support on residents' health, the overall frequency of residential relocation has a negative impact on residents' physical and mental health. Overall, physical health is more affected by the cumulative effects of residential relocation than mental health. From the perspective of relocation frequency at different stages, residential relocation has both short-term and long-term cumulative effects, with varying degrees of impact at different stages. For the elderly population, the frequency of relocation within 5 years has a significant impact on both physical and mental health, and this impact mechanism has a typical short-term effect. This conclusion is similar to existing studies. As the elderly move to a new location, their inner anxiety gradually weakens with the extension of living time, and their mental health level continues to improve [43,44]. The findings showed that the elderly who moved more frequently within 5 years had worse physical health, and those who moved more frequently also had worse mental health. However, with the longer time interval of the elderly's relocation, their mental health showed a significant trend of improvement. Elderly people who moved actively had better physical and mental health than those who moved passively. Elderly individuals who moved across administrative regions had poorer mental health. However, due to the short relocation distance, the elderly living in the area are in relatively good physical health.

Table 7. Descriptive statistics of residential relocation and health among the elderly.

Relocation Attribute			Physical Health		Mental Health		Total Samples/Numbers
			Poor/%	Good/%	Poor/%	Good/%	
Relocation frequency	Number of relocations in 5 years	0 time	27.83	72.17	34.79	65.21	848
		1 time	26.32	73.68	45.61	54.39	171
		2 time	80.00	20.00	100.00	0.00	10
	Number of relocations in 3 years	0 time	25.67	74.33	37.32	62.68	822
		1 time	33.90	66.10	36.99	63.01	177
		2 time	60.00	40.00	40.32	59.68	30
		3 time	0.00	0.00	0.00	100.00	4
	Number of relocations in 1 year	0 time	25.67	74.33	38.20	61.80	822
		1 time	33.90	66.10	31.64	68.36	177
		2 time	60.00	40.00	43.33	56.67	30
Relocation interval	Interval period	Within 1 year	35.00	65.00	55.00	45.00	40
		2–3 years	23.77	76.23	50.00	50.00	122
		4–5 years	25.00	75.00	36.21	63.79	116
		More than 5 years	28.89	71.11	34.35	65.65	751

Table 7. *Cont.*

Relocation Attribute			Physical Health Poor/%	Physical Health Good/%	Mental Health Poor/%	Mental Health Good/%	Total Samples/Numbers
Relocation characteristics	Relocation willingness	passive	40.43	59.57	50.00	50.00	94
		active	26.84	73.16	35.94	64.06	935
		No relocation	23.04	76.96	34.35	65.65	230
	Relocation direction	Inner City-Inner City	31.93	68.07	31.02	68.98	548
		Inner City-Outer City	25.96	74.04	36.54	63.46	104
		Outer City-Inner City	22.88	77.12	65.25	34.75	118
		Outer City-Outer City	24.14	75.86	65.52	34.48	29
	Average relocation distance		6.39/km	6.51/km	7.76/km	5.72/km	6.48/km

To exclude the possible collinearity correlation between physical health indicators and mental health indicators, we conducted a cross-tabulation test on these two attributes (Table 8). The sig value of Pearson's chi-square test was 0.012, which is less than 0.05. The results show that there are differences between residents' physical and mental health that need to be classified.

Table 8. Cross-analysis of residents' physical and mental health.

		Physical Health Poor/%	Physical Health Good/%			Mental Health Poor/%	Mental Health Good/%	Pearson's Chi-Square Test
Mental health	Poor	32.64	67.36	Physical health	Poor	43.25	56.75	0.012
	Good	25.39	74.61		Good	34.86	65.14	
Number of samples		289	740	Number of samples		289	740	

3.2. Cumulative Effect of Relocation Frequency on the Elderly's Health

Relocation may have a cumulative effect on health, which is related to the life stage of the elderly. With the continuous accumulation of relocation frequency, the effect of relocation on health gradually increases. In this study, the elderly's relocation frequency was divided into three periods: 1 year, 3 years and 5 years. The model takes relocation frequency as the dependent variable, sets the reference value of physical health and mental health as 1, and conducts a binomial logistic regression analysis. The validity of the model was verified, and the reliability of the results was acceptable (Table 9). This study's findings are consistent with existing studies, mainly as follows. First, frequent relocation within 5 years harms the physical health of the elderly, especially those who do not exercise regularly [42]. Second, frequent relocation within 5 years adversely affects the mental health of the elderly, which has a significant negative impact on the mental health of married elderly, thus leading to the generation of problem behaviors in the elderly [42,57]. Third, recent relocation is more likely to cause inadaptability pressure on the elderly, which will negatively impact their health [32]. Finally, frequent relocation had a significant impact on the mental health of elderly people with different incomes. This phenomenon may be related to the emphasis of the elderly on stable living conditions [55].

Table 9. Models of how relocation frequencies affect health (cumulative effect model).

Variable	Physical Health (Cox and Snell R^2 = 0.184, Accuracy = 76.3%)				Mental Health (Cox and Snell R^2 = 0.175, Accuracy = 70.1%)			
	Coef.	S.E.	95% CI		Coef.	S.E.	95% CI	
			Lower Limit	Upper Limit			Lower Limit	Upper Limit
Relocation frequency								
Within 5 years	**−0.664** ***	0.515	0.345	0.769	**−0.700** ***	0.496	0.345	0.714
Within 3 years	−0.037	0.964	0.735	1.264	−0.095	0.909	0.705	1.172
Within 1 year	**−0.364** *	0.695	0.502	0.963	−0.080	0.923	0.671	1.270
Personal habits								
Smoking # Yes	−0.022	0.979	0.568	1.684	0.394	1.482	0.921	2.385
Drinking # Yes	−0.236	0.790	0.513	1.218	−0.067	0.935	0.641	1.365
Exercise # Yes	**−0.636** ***	0.529	0.365	0.768	−0.216	0.805	0.578	1.123

Table 9. *Cont.*

Variable	Physical Health (Cox and Snell R^2 = 0.184, Accuracy = 76.3%)				Mental Health (Cox and Snell R^2 = 0.175, Accuracy = 70.1%)			
	Coef.	S.E.	95% CI		Coef.	S.E.	95% CI	
			Lower Limit	Upper Limit			Lower Limit	Upper Limit
Individual socio-economic attributes								
Gender # Female	−0.263	0.768	0.454	1.300	0.025	1.026	0.646	1.629
Age	**−0.084** ***	0.919	0.905	0.934	−0.008	0.992	0.979	1.006
Marital status # unmarried								
Married	0.267	1.306	0.781	2.184	**−0.583** **	0.472	0.010	0.736
Divorced or widowed	−1.452	0.234	0.012	4.754	0.752	0.263	0.014	1.009
Annual family income #More than 40,000								
Less than 10,000	−1.429	0.240	0.027	2.163	**−2.465** *	0.085	0.015	1.140
10,000–20,000	−1.190	0.304	0.034	2.729	**−2.142** *	0.117	0.026	8.701
20,000–40,000	−1.259	0.284	0.031	2.615	**−2.050** *	0.129	0.015	4.688
Neighborhood and social support								
Number of relatives	−0.060	0.942	0.768	1.155	0.004	1.004	0.764	1.319
Neighborhood relations	−0.009	0.991	0.946	1.038	**0.240** ***	1.271	1.213	1.332
Number of acquaintances	-	-	-	-	0.082	1.085	0.865	1.361
Density of medical facilities	**0.071** **	1.074	1.023	1.128	-	-	-	-

Note: The dependent variable 1 refers to good health and 0 refers to poor health. # refers to reference variables (control group). represents no parameter, which means that the variable is not in the model. * indicates 0.1 significance level, ** indicates 0.01 significance level and *** indicates a significance level of 0.005 or above.

3.3. The Effect of Short-Term Relocation Experience on the Elderly's Health

The elderly require an adaptation period after each move. This period has a negative impact on the physical and mental health of the elderly. The model tests the health effects of elderly people living in a new house for a long time. All independent variables related to relocation behavior were included in the health effect model, and the fitting effect was acceptable (Table 10). We control for relevant indicators, such as individual socio-economic attributes in the model, and find the following significant conclusions. First, compared with the elderly who have lived for more than 5 years, the probability of the elderly who have moved within 1 year to maintain health has decreased by 1.251 times. Within 2–3 years of relocation, the elderly's probability of maintaining mental health decreased by 1.074 times. With the continuous growth in the elderly's stay time, the impact of the adaptation period of relocation significantly decreased. Second, the length of relocation had a significant negative impact on male groups and the elderly who lack exercise. The short-term relocation experience has a significant negative impact on the mental health of the elderly. In particular, in terms of social neighborhood relations, short-term relocation experiences had a significant negative impact on the psychological health of the elderly. This outcome is similar to the conclusions of previous studies [43].

3.4. The Influence of Relocation Characteristics on the Elderly's Health

We further analyzed the influence of characteristics, such as relocation intention, direction, and distance on the elderly's health. In general, the influence of relocation characteristics on elderly health differed significantly. We included the relocation characteristics in the binomial logistic regression model, and the goodness of fit of the model reached a credible level (Table 11). The willingness to relocate has a significant impact on the elderly's physical health but has no significant impact on their mental health. Specifically, compared with the elderly who move actively, those who move passively are more likely to be physically unhealthy. Generally, the purpose of active relocation is to improve living conditions. A good living environment is conducive to the maintenance of physical and mental health among older adults. However, the relocation process consumes much of the physical strength of elderly people. Elderly people still need to adapt to the new environment after relocation; hence, these factors can harm the elderly both physically and mentally.

Table 10. Models of how relocation frequencies affect health (short-term effect model).

Variable	Physical Health (Cox and Snell R^2 = 0.181, Accuracy = 75.2%)				Mental Health (Cox and Snell R^2 = 0.171, Accuracy = 69.7%)			
	Coef.	S.E.	95% CI		Coef.	S.E.	95% CI	
			Lower Limit	Upper Limit			Lower Limit	Upper Limit
Move in period after relocation # 5 years or more								
Within 1 year	**−1.250** ***	0.287	1.251	0.608	**−1.074** ***	0.342	0.165	0.706
2–3 years	−0.216	0.805	0.486	1.334	**−0.571** **	0.565	0.366	0.871
4–5 years	0.171	1.187	0.702	2.006	−0.015	0.985	0.625	1.554
Personal habits								
Smoking # Yes	−0.037	0.964	0.561	1.655	0.387	1.473	0.916	2.368
Drinking # Yes	−0.253	0.776	0.504	1.196	−0.087	0.916	0.628	1.337
Exercise # Yes	**−0.624** ***	0.536	0.369	0.777	−0.195	0.823	0.590	1.147
Individual socio-economic attributes								
Gender # Female	−0.291	0.748	0.444	1.258	0.003	1.003	0.632	1.593
Age	**−0.086** ***	0.917	0.903	0.932	−0.009	0.991	0.978	1.004
Marital status # unmarried								
Married	0.192	1.211	0.722	2.033	**−0.666** ***	0.539	0.011	0.793
Divorced or widowed	−1.390	0.249	0.013	4.920	0.619	0.277	0.014	1.056
Annual family income # more than 40,000								
Less than 10000	−1.465	0.231	0.025	2.155	**−2.390** *	0.092	0.015	1.202
10,000–20,000	−1.235	0.291	0.031	2.697	**−2.098** *	0.123	0.032	9.016
20,000–40,000	−1.298	0.273	0.029	2.592	**−1.998** **	0.136	0.017	4.490
Neighborhood and social support								
Number of relatives	−0.038	0.962	0.785	1.179	0.014	1.014	0.771	1.333
Neighborhood relations	−0.013	0.987	0.942	1.034	**0.239** ***	1.270	1.213	1.331
Number of acquaintances	-	-	-	-	0.086	1.089	0.868	1.367
Density of medical facilities	**0.077** ***	1.080	1.028	1.133	-	-	-	-

Note: The dependent variable 1 refers to good health and 0 refers to poor health. # refers to reference variables (control group). represents no parameter, which means that the variable is not in the model. * indicates 0.1 significance level, ** indicates 0.01 significance level and *** indicates a significance level of 0.005 or above.

Table 11. The influence model of residential characteristics on residents' health.

Variable	Physical Health (Cox and Snell R^2 = 0. 194, Accuracy = 76.8%)				Mental Health (Cox and Snell R^2 = 0. 219, Accuracy = 72.7%)			
	Coef.	S.E.	95% CI		Coef.	S.E.	95% CI	
			Lower Limit	Upper Limit			Lower Limit	Upper Limit
Relocation characteristics								
Relocation willingness # actively								
Negative	**−0.896** *	0.408	0.207	0.804	0.045	1.046	0.533	2.053
Relocation distance	0.003	1.003	0.967	1.040	**−0.039** *	0.962	0.930	0.994
Relocation direction # outer city- outer city								
inner city-inner city	−0.488	0.614	0.203	1.852	**0.874** *	2.396	0.946	6.067
inner city-outer city	−0.418	0.659	0.215	2.019	**0.830** *	2.292	0.863	6.091
outer city-inner city	−0.056	0.945	0.311	2.874	−0.518	0.596	0.225	1.576
Personal habits								
Smoking # Yes	−0.250	0.779	0.423	1.435	0.214	1.239	0.700	2.193
Drinking # Yes	−0.250	0.779	0.471	1.288	−0.078	0.925	0.588	1.453
Exercise # Yes	**−0.709** ***	0.492	0.324	0.747	−0.242	0.785	0.537	1.148
Individual socio-economic attributes								
Gender # Female	−0.161	0.852	0.477	1.519	0.028	1.029	0.595	1.778
Age	**−0.086** ***	0.918	0.902	0.934	−0.012	0.988	0.973	1.003
Marital status # unmarried								
Married	0.469	1.598	0.889	2.874	**−0.491** *	0.612	0.367	1.021
Divorced or widowed	−20.223	0.000	0.000	0.000	−0.487	0.614	0.024	15.910
Annual family income #More than 40,000								
Less than 10,000	−0.886	0.412	0.048	3.513	**−2.696** *	0.067	0.006	0.811
10,000–20,000	−1.016	0.362	0.043	3.016	**−2.253** *	0.105	0.009	1.244
20,000–40,000	−1.084	0.338	0.039	2.897	−2.013	0.134	0.011	1.621
Neighborhood and social support								
Number of relatives	−0.010	0.990	0.784	1.252	0.062	1.064	0.768	1.475
Neighborhood relations	−0.042	0.959	0.909	1.011	**0.235** ***	1.264	1.196	1.337
Number of acquaintances	-	-	-	-	0.182	1.200	0.920	1.564
Density of medical facilities	**0.110** ***	1.116	1.053	1.183	-	-	-	-

Note: The dependent variable 1 refers to good health and 0 refers to poor health. # refers to reference variables (control group). represents no parameter, which means that the variable is not in the model. * indicates 0.1 significance level and *** indicates a significance level of 0.005 or above.

As a result of these multiple factors, the willingness to relocate has no significant impact on the physical health of the elderly, and relocation is not conducive to the maintenance of the elderly's physical health. The model results outline that the longer the relocation distance, the greater the possibility of mental illness among the elderly, but this indicator has no significant impact on physical health. The closer the relocation distance, the less difficult it is for the elderly to adapt to the new environment, which is more conducive

to the maintenance of mental health among the elderly. In terms of relocation direction, compared with relocation within the outer circle, internal and centrifugal relocation within the core area has a positive effect on the mental health of the elderly. Generally, the core area is relatively small, and various public service facilities are relatively complete [42]. Thus, the elderly have a short relocation distance in urban core areas and little environmental change. Compared with cross-regional relocation, relocation to the core area is more conducive to maintaining the psychological health of the elderly. Studies have shown that the elderly move from the main urban area to the suburbs to obtain better living conditions [38]. From this study, the relocation of the main city to the outer ring is more conducive to the psychological health of the elderly; however, the relocation direction has no significant impact on the physical health of the elderly.

4. Discussion

4.1. Frequent Residential Relocation Negatively Impacts Elderly's Health

We controlled for the indicators related to social and economic attributes among the elderly, living habits and neighborhood social support. The results of the model show that frequent residential relocation has a significant negative impact on the physical and mental health of the elderly. Specifically, the elderly's residential relocation frequency within 3–5 years has a significant negative impact on their health, specifying that there is a short-term effect of residential relocation behavior on their health. This result is similar to existing research findings [44]. This study conducts statistical analysis on the relocation behavior of residents in major developed countries internationally. The study classified and described residents by different age groups, believing that frequent relocation in urban areas can make it difficult for elderly people to adapt to different living environments, leading to internal anxiety and health damage. There are other papers that focus on the impact of different racial immigrants' relocation behavior in cities on life satisfaction from the perspective of differences socio-economic background [45]. The results indicate that the majority of elderly people have weak socio-economic activities, and frequent relocation behaviors can disrupt their daily habits, leading to psychological anxiety and unease [45]. In the past year, the elderly's residential relocation frequency had a significant negative impact on their physical health but had no significant impact on their mental health. The results showed that short-term residential relocation behavior greatly consumed the elderly's energy, and the elderly needed to readapt to the external environment. The negative effects of residential relocation frequency on the physical and mental health of the elderly were significant, but the negative effects were weakened after the elderly adapted to the new living environment.

4.2. The Health Effects of Residential Relocation on Different Stages Are Heterogeneous

The cumulative effect of residential relocation harmed the physical and mental health of the elderly. In terms of cumulative effects, frequent residential relocation among the elderly in the past 5 years had a significant negative impact on their health. In the past 3 years, residential relocation behavior has significantly affected the physiological health of the elderly. In terms of short-term effects, the shorter the elderly moved to a new residence, the more significant their physical and mental health would be. The results of this article are similar to the existing studies. After elderly people move to new homes, it takes them a long time to adapt to the surrounding environment and stabilize their inner emotions [46]. Multiple relocations within a fixed time quantum will accumulate psychological stress of the elderly, and long-term anxiety will also lead to a decline in the health level of the elderly [49,57]. In terms of the characteristics of residential relocation behavior, the elderly's active residential relocation had a significant positive impact on their physiological health. Residential relocation distance has a significant negative impact on the mental health of the elderly. Centrifugal residential relocation (from the main urban area to the surrounding new urban area) had a significant positive impact on the mental health of the elderly (Table 12).

Table 12. Effect of relocation on residents' physical and mental health.

Type	Primary Indicators	Secondary Indicators	Physical Health OR [95% CI]	Mental Health OR [95% CI]
Cumulative effects	Relocation frequency	once within 5 years	↓0.695 [0.502–0.963]	↓0.496 [0.345–0.714]
		2–3 times within 5 years	/	/
		4–5 times within 5 years	↓0.515 [0.345–0.769]	/
Short-term effects	Relocation time (# 5 + years)	Within 1 year	↓0.287 [0.135–0.608]	↓0.342 [0.165–0.706]
		2–3 years	/	↓0.571 [0.366–0.871]
		3–5 years	/	/
Relocation characteristics effects	Relocation willingness (# Active)	Passive	↓0.408 [0.207–0.804]	/
	Relocation direction (# outer→outer)	Inner city→Inner city	/	↑2.396 [0.946–6.067]
		Outer city→Inner city	/	↑2.292 [0.863–6.091]
		Inner city→Outer city	/	/
	Relocation distance	/	/	↓0.962 [0.930–0.994]

Note: Among the measurement indicators, "healthy" is defined as 1, and "unhealthy" is defined as 0; #; ↑ represents a positive impact, ↓ represents a negative impact, and / represents no significant impact.

4.3. The Impact of Relocation on Health Shows a Multifactor Mixed Cross Action

In previous studies, sociologists and psychologists have used the social-ecological theory to describe the impact of the external environment on human behavior and psychology [18]. This theory regards people in society as creatures in the ecosystem and believes that human behavior and psychological state are jointly affected by internal factors (emotion, motivation, belief, etc.) and external factors (social environment, policy environment, economic conditions, etc.) [38,58]. Based on the theoretical model of social ecology, we built a mechanistic model of the impact of relocation on residents' physical and mental health, as illustrated in Figure 7. The frequency, duration, direction and distance of relocation are external factors, whereas willingness to relocate is an internal factor. Additionally, personal physical and mental health, as the dependent variables of the model, are also internal factors. It can be seen from the analysis results that the relocation will consume the energy of the elderly, which causes the elderly to not adapt to a new environment within a certain period. Therefore, relocation activity is not conducive to the physical and mental health of the elderly in the short term. Furthermore, the longer relocation distance makes it more difficult for the elderly to adapt to the new environment, thereby enhancing the negative impact on their mental health. At the same time, the high frequency of relocation will also overdraw the physical strength of the elderly, which is not conducive to their physical and mental health. From the perspective of the built environment, most newly built residential areas in Nanjing are located in the suburbs. These residential areas have good natural environments, low building densities and complete public service facilities. Elderly people further improved their living conditions through active outward relocation activities. A good living environment is conducive to maintaining the physical and mental health of older adults.

4.4. The Living Habits and External Environment Have a Significant Impact on the Elderly's Health

In terms of control variables, the elderly's personal habits had a significant impact on their physiological health. Specifically, elderly people who do not exercise regularly are more likely to be physically unhealthy. This conclusion is consistent with the general cognition that regular exercise is beneficial to improving residents' physiological health in existing studies [49]. In the socio-economic attributes, age has a significant negative impact on the physical health of the elderly. With increasing age, it becomes more difficult for the elderly to maintain their physical health. This conclusion is consistent with the general decline in physical health among the elderly [50]. Marital status has a significant impact on the mental health of older adults. Unmarried and widowed elderly are more likely to be psychologically unhealthy. Elderly widowed people may bear greater economic

pressure, which negatively affects their mental health. Annual family income also has a significant impact on the mental health of the elderly. Compared with residents with an income of more than 40,000, the elderly with an income of less than 10,000, 10,000 to 20,000 and 20,000 to 40,000 are more likely to be psychologically unhealthy. This conclusion is consistent with existing research that high-income groups are more likely to avoid mental health problems [59]. The higher the accessibility of medical facilities around the residential area, the significantly positive the impact on physical health among the elderly. Generally, when medical facilities around the residential area are abundant, the higher the convenience of the elderly in obtaining medical resources, the greater the probability of the elderly maintaining physical health. Moreover, a good neighborhood relationship can significantly and positively affect the mental health of the elderly, which is consistent with the conclusions of previous studies [60].

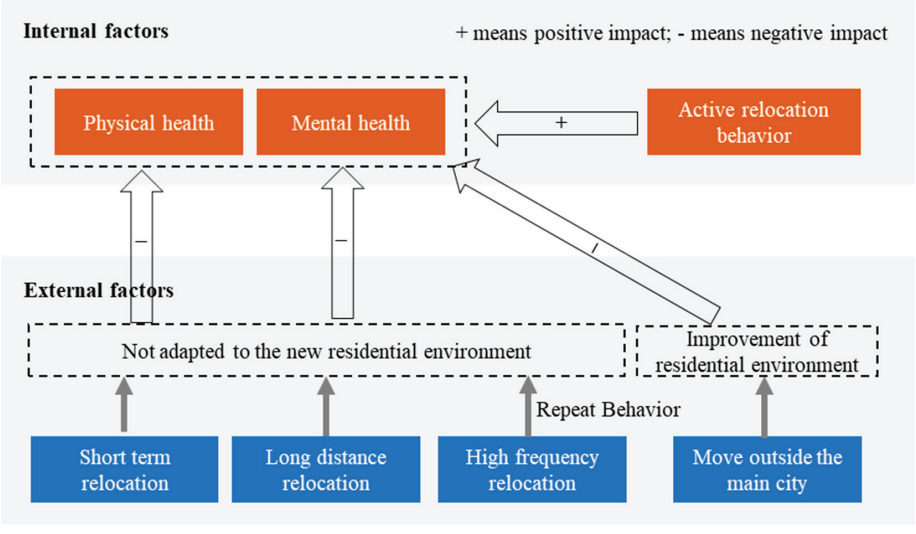


Figure 7. The influence path of relocation on residents' physical and mental health.

5. Conclusions

5.1. Key Findings

Taking Nanjing as an example, this study used binomial logistic regression analysis and in-depth interviews to study relocation behavior. We used 2019 household survey questionnaire data. This paper analyses the influence of the spatial and temporal characteristics of the elderly's relocation, the accumulation effect at different stages and the willingness to move on the physical and mental health among the elderly. The findings show that the effects of relocation on elderly health include long-term cumulative effects and short-term effects, which are mainly reflected in the following aspects.

(1) The frequency of relocation of residents in Nanjing has generally increased and has increased significantly since 2000. From the perspective of spatial distribution patterns, the ratio of the elderly moving from the peripheral suburbs to the main urban area was high, and only a small proportion of the elderly moved from the main city to the suburban new town;

(2) Frequent relocation harms the health of the elderly. The long-term cumulative effect is shown as the negative impact of frequent relocation over the past 5 years on the physical and mental health of the elderly. The short-term effect refers to the negative impact of the elderly's relocation on their mental health in the short term;

(3) Different relocation characteristics had different effects on health. Regarding the last relocation activity, active relocation had a significant positive impact on physical health, centrifugal relocation had a significant positive impact on mental health and long-distance relocation had a significant negative impact on mental health;
(4) The effect of relocation on health is multifactorial. The longer relocation distance makes it more difficult for the elderly to adapt to the new environment, which has a significant negative impact on their psychological health. At the same time, high frequency relocation consumes a lot of the physical strength of the elderly, which is not conducive to their physical and mental health.

5.2. Implications

This study summarizes the time–space characteristics of relocation from the perspective of geography and analyses the impact of relocation behavior on health under long-term and short-term time effects. This study evaluated the differential effects of relocation distance, direction and intention on residents' physical and mental health. From the perspective of geography, this study supplements relevant theoretical research results on relocation behavior. Generally, urban internal relocation has a significant impact on the elderly's health. The physical health of the elderly was significantly affected by long-term cumulative effects, while their mental health was significantly affected by short-term effects. Both the short- and long-term effects of relocation adversely affected residents' physical and mental health. The state needs to formulate a planning policy to maintain long-term stable residences for the elderly. A stable living environment is conducive to improving the physical and mental health of older adults. Stable social relationships and close neighborhood exchanges are conducive to the physical and mental health of the elderly. The government should actively build a stable community relationship network, and relevant positive measures will be conducive to improving residents' health. For the elderly population, the focus of relocation is to build a familiar neighborhood environment. A familiar neighborhood environment can enhance the elderly's social interaction level, alleviate their psychological anxiety and loneliness and help maintain a healthy living state for the elderly. On the other hand, the renewal of old urban residential areas should not simply adopt the development model of inner-city demolition and suburban reconstruction. The location environment remains the primary factor affecting the living quality for the elderly. A good neighborhood environment plays a greater role than the quality of residential buildings. The community construction should strengthen the creation of an aging-friendly environment, allowing elderly people to quickly integrate into the community's life circle and neighborhood social networks, and improving their sense of happiness and satisfaction.

5.3. Limitations and Future Research Directions

Through a follow-up survey of the health status of the elderly, this study discusses the mechanism of the impact of relocation on health. However, there are still some areas worth discussing in this study. First, the positive effect of active relocation and the negative effect of relocation intersect. Second, the adaptation period of the elderly to a new residence was not fixed. These findings need to be further analyzed in future research. Moreover, it is difficult to explain the short-term effect mechanism of relocation on health and deconstruct the mechanism of external factors on direct variables, such as relocation duration, through models. This article selects the elderly population as the research object, which has limitations in sample selection, and the sampling proportion still needs further verification. We cannot accurately obtain the proportion and location of the elderly population in urban areas. We selected several representative residential areas with a large number of elderly people for sampling surveys, but the distribution of the samples did not cover the entire city and there is still bias. In the next step, we will conduct more extensive sample research to improve the explanatory power of the model results.

In future research, we will explain the impact of relocation on health through longitudinal follow-up research on health status. We will further analyze the self-regulation

process of the short-term effects of relocation on the health of the elderly. We will track the elderly's health across 3 months, 6 months and 1 year. Additionally, we will conduct in-depth interviews and other research methods, focusing on a more comprehensive discussion of the mechanism of the impact of relocation on health. In a follow-up study, we also plan to conduct in-depth research on population differentiation and combine social spatial differentiation with relocation to conduct cross-cutting research in multiple fields. Social spatial differentiation and relocation may have an interactive relationship, and we will perform structural equation modelling to conduct an in-depth analysis of their structural relationships in a follow-up study.

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References

1. Maeng, D.M.; Budic, Z.N. Relationship between ICT and urban form in knowledge-based development: Empirical analysis of Washington, DC metro region. *Int. J. Knowl.-Based Dev.* **2010**, *1*, 97–117. [CrossRef]
2. Beenackers, M.A.; Foster, S.; Kamphuis, C.B.; Titze, S.; Divitini, M.; Knuiman, M.; Van Lenthe, F.J.; Giles-Corti, B. Taking up cycling after residential relocation: Built environment factors. *Am. J. Prev. Med.* **2012**, *42*, 610–615. [CrossRef]
3. Camargo, O.; Preston, G.H. What happens to patients who are hospitalized for the first time when over sixty-five years of age. *Am. J. Psychiatry* **1945**, *102*, 168–173. [CrossRef]
4. Blenkner, M. Environmental Change and the Aging Individual. *Gerontol.* **1967**, *7*, 101–105. [CrossRef]
5. Borup, J.H.; Gallego, D.T.; Heffernan, P.G. Relocation and its Effect on Mortality. *Gerontol.* **1979**, *19*, 135–140. [CrossRef]
6. Ben-Shlomo, Y.; Kuh, D. A life course approach to chronic disease epidemiology: Conceptual models, empirical challenges and interdisciplinary perspectives. *Int. J. Epidemiol.* **2002**, *31*, 285–293. [CrossRef] [PubMed]
7. Jelleyman, T.; Spencer, N. Residential relocation in childhood and health outcomes: A systematic review. *J. Epidemiol. Community Health* **2008**, *62*, 584–592. [CrossRef] [PubMed]
8. Ludwig, J.; Duncan, G.J.; Gennetian, L.A.; Katz, L.F.; Kessler, R.C.; Kling, J.R.; Sanbonmatsu, L. Neighborhood Effects on the Long-Term Well-Being of Low-Income Adults. *Science* **2012**, *337*, 1505–1510. [CrossRef] [PubMed]
9. Mirotznik, J.; Lombardi, T.G. The Impact of Intrainstitutional Relocation on Morbidity in an Acute Care Setting. *Gerontol.* **1995**, *35*, 217–224. [CrossRef]
10. Lander, S.M.; Brazill, A.L.; Ladrigan, P.M. Intrainstitutional relocation: Effects on residents' behaviour and psychosocial functioning. *J. Gerontol. Nurs.* **1997**, *23*, 35–41. [CrossRef]
11. Yang, Y.; Zhou, Y.; Qiu, P. A review of research on the impact of urban spatial differentiation on health in the academic community of Europe and America. *Chin. J. Soc. Med.* **2013**, *30*, 3. [CrossRef]
12. Kingdon, G.G.; Knight, J. Community, comparisons and subjective well-being in a divided society. *J. Econ. Behav. Organ.* **2007**, *64*, 69–90. [CrossRef]
13. Gilbert, L.; Soskolne, V. Self-assessed health—A case study of social differentials in Soweto, South Africa. *Health Place* **2003**, *9*, 193–205. [CrossRef] [PubMed]
14. Chen, H.; Li, Z. A Study on the Differentiation of Housing Rights in Large Chinese Cities under Rapid Urbani-zation: An Empirical Study of Guangzhou. *J. Geogr.* **2015**, *69*, 1821–1832.
15. Haight, B.K.; Michel, Y.; Hendrix, S. Life Review: Preventing Despair in Newly Relocated Nursing Home Residents Short- and Long-Term Effects. *Int. J. Aging Hum. Dev.* **1998**, *47*, 119–142. [CrossRef]
16. Adam, E.K.; Chase-Lansdale, P.L. Home sweet home(s): Parental separations, residential moves, and adjustment problems in low-income adolescent girls. *Dev. Psychol.* **2002**, *38*, 792–805. [CrossRef]
17. Lin, K.C.; Twisk, J.W.R.; Huang, H.C. Longitudinal impact of frequent geographic relocation from adolescence to adulthood on psychosocial stress and vital exhaustion at ages 32 and 42 years: The Amsterdam growth and health longitudinal study. *J. Epidemiol.* **2012**, *22*, 469–476. [CrossRef]

18. Chetty, R.; Hendren, N.; Katz, L.F. The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment. *Am. Econ. Rev.* **2016**, *106*, 855–902. [CrossRef]
19. Kasl, S.V. Physical and mental health effects of involuntary relocation and institutionalization on the elderly: A review. *Am. J. Public Health* **1972**, *62*, 377–384. [CrossRef]
20. Schaefer, C.; Coyne, J.C.; Lazarus, R.S. The health-related functions of social support. *J. Behav. Med.* **1981**, *4*, 381–406. [CrossRef]
21. Murphy, E. Social Origins of Depression in Old Age. *Br. J. Psychiatry* **1982**, *141*, 135–142. [CrossRef] [PubMed]
22. Hong, S.I.; Chen, L.M. Contribution of residential relocation and lifestyle to the structure of health trajectories. *J. Aging Health* **2009**, *21*, 244–265. [CrossRef]
23. Stokols, D.; Shumaker, S.A. The psychological context of residential relocation and weil-being. *J. Soc. Issues* **1982**, *38*, 149–171. [CrossRef]
24. Goering, J.; Kraft, J.; Feins, J.; McInnis, D.; Holin, M.J.; Elhassan, H. *Moving to Opportunity for Fair Housing Demonstration Program: Status and Initial Findings*; US Department of Housing and Urban Development: Washington, DC, USA, 1999.
25. Coleman, J.S. Social capital in the creation of human capital. *Am. J. Sociol.* **1988**, *94*, S95–S120. [CrossRef]
26. Chen, H.S.; Li, Z.G. Tenure-based housing segregation under rapid urbanization in post-reform urban China: A case study of Guangzhou. *Acta Geogr. Sin.* **2014**, *69*, 1821–1832.
27. Liu, R.; Guan, C.-Q. Mode Biases of Urban Transportation Policies in China and Their Implications. *J. Urban Plan. Dev.* **2005**, *131*, 58–70. [CrossRef]
28. Feng, J.; Zhou, Y.X. Intra-urban residential relocation and correlative spatial behaviour in Beijing in the process of suburbanization: Based on 1000 questionnaires. *Geogr. Res.* **2004**, *23*, 227–242.
29. He, X.S.; Huang, F.Q.; Zeng, S.C. Rural-urban residential relocation and mental health: Evidence from Shanghai. *Sociol. Stud.* **2010**, *33*, 111–129.
30. Hou, M.; Wang, M.J. A review on studies about residents' behaviour of changing residence. *J. Cap. Norm. Univ. Nat. Sci. Ed.* **2014**, *35*, 95–100.
31. Ji, L. Chengshihua youliyu jiankang ma?: Jiyu geti weiguan qianyi shuju de shizhengyanjiu. *World Econ. Pap.* **2013**, *3*, 18–28.
32. Anastasio, R.J.; Leventhal, T.; Amadon, S. High residential mobility and young children's healthy development in low-income families: Exploring the moderating role of Head Start. *Early Child. Res. Q.* **2022**, *59*, 96–108. [CrossRef]
33. de la Prada, G. Understanding Out-Mobility and Radical-Right Support as Responses to Differentiated Refugee Exposure. *J. Refug. Stud.* **2022**, *35*, 1030–1053. [CrossRef]
34. Gregoricka, L.A.; Baker, B.J. Residential Mobility, Pastoralism, and Community in Ancient Kush. *Am. J. Phys. Anthropol.* **2021**, *71*, 174–176.
35. Liu, S.S.T. Heterogeneous housing choice and residential mobility under housing reform in China: Evidence from Tianjin. *Appl. Geogr.* **2021**, *129*, 102417. [CrossRef]
36. Li, P.F.; Chai, Y.W. The influence of housing residential relocation on daily life social network among the elderly in Danwei. *Hum. Geogr.* **2013**, *28*, 78–84.
37. Hou, Y.; Duan, C. Re understanding of data on the younger population in the Chinese population census. *China Popul. Yearb.* **2019**, *13*, 294.
38. Li, Z.B.; Tan, Y.; Cheng, G.S. Involuntary residential relocation, relative income and the immigrant health. *J. South-Cent. Univ. Natl. Nat. Sci. Ed.* **2009**, *28*, 122–126.
39. Li, Z.G.; Wu, F.L. Sociospatial differentiation in transitional Shanghai. *Acta Geogr. Sin.* **2006**, *61*, 199–211.
40. Sun, B.D.; Wu, Y.F. Progress and prospect of residential spatial differentiation of Chinese cities. *City Plan. Rev.* **2009**, *33*, 73–80.
41. Zhong, T.; Xu, W.; Hu, L. Progress of the researches on the social ecological model of physical activity. *Sport Sci. Res.* **2014**, *35*, 28–31.
42. Zhou, S.H.; Liu, Y.L. The situation and transition of jobs-residential relocation in Guangzhou, China. *Acta Geogr. Sin.* **2010**, *65*, 191–201.
43. Xue, F.; Yao, E.; Jin, F. Exploring residential relocation behavior for families with workers and students; a study from Beijing, China. *J. Transp. Geogr.* **2020**, *89*, 102893. [CrossRef]
44. Lichun, Q.; Jianwen, Y. Study on Central Government Behavior in China Regional Industry Relocation. *Contemp. Econ. Manag.* **2013**, *37*, 56–59.
45. Matarrita-Cascante, D.; Sene-Harper, A.; Stocks, G. International amenity migration: Examining environmental behaviors and influences of amenity migrants and local residents in a rural community. *J. Rural. Stud.* **2015**, *38*, 1–11. [CrossRef]
46. Liang, Y.; Wei, Y.; Wang, S.; Gong, S.; Dong, Y.; Gao, L.; Wang, S.; Zhou, Y.; Ye, N. Impact of International Immigration on Life Satisfaction of Local Residents in England: Exploring the Differentiated Relationships across Socioeconomic Gradients. *Am. J. Health Behav.* **2019**, *43*, 866–976. [CrossRef]
47. Hodgson, N.; Freedman, V.A.; Granger, D.A.; Erno, A. Biobehavioral Correlates of Relocation in the Frail Elderly: Salivary Cortisol, Affect, and Cognitive Function. *J. Am. Geriatr. Soc.* **2010**, *52*, 1856–1862. [CrossRef]
48. Brown, A.C.; Orthner, D.K. Relocation and Personal Well-Being among Early Adolescents. *J. Early Adolesc.* **1990**, *10*, 366–381. [CrossRef]
49. Nguyen, Q.C.; Acevedo-Garcia, D.; Schmidt, N.M.; Osypuk, T.L. The Effects of a Housing Mobility Experiment on Participants' Residential Environments. *Hous. Policy Debate* **2017**, *27*, 419–448. [CrossRef]

50. Bronfenbrenner, U. Toward an experimental ecology of human development. *Am. Psychol.* **1977**, *32*, 513–531. [CrossRef]
51. Osypuk, T.L.; Tchetgen, E.J.T.; Acevedo-Garcia, D.; Earls, F.J.; Lincoln, A.; Schmidt, N.M.; Glymour, M.M. Differential mental health effects of neighborhood relocation among youth in vulnerable families: Context. *JAMA Psychiatry* **2012**, *69*, 1284–1294. [CrossRef]
52. Dekel, R. Mental Health Practitioners' Experiences During the Shared Trauma of the Forced Relocation from Gush Katif. *Clin. Soc. Work. J.* **2010**, *38*, 388–396. [CrossRef]
53. Bures, R.M. Childhood Residential Stability and Health at Midlife. *Am. J. Public Health* **2003**, *93*, 1144–1148. [CrossRef]
54. Dimond, M.; McCance, K.; King, K.; Benoliel, J.Q.; Chang, B.L. Forced residential relocation: Its impact on the well-being of older adults. *West. J. Nurs. Res.* **1987**, *9*, 445–464. [CrossRef]
55. Jones-Rounds, M.L.; Evans, G.W.; Braubach, M. The interactive effects of housing and neighbourhood quality on psycho-logical well-being. *J. Epidemiol. Community Health* **2014**, *68*, 171–175. [CrossRef]
56. Juon, H.-S.; Ensminger, M.E.; Feehan, M. Childhood Adversity and Later Mortality in an Urban African American Cohort. *Am. J. Public Health* **2003**, *93*, 2044–2046. [CrossRef]
57. Xu, J.L.; Jiao, H.F.; Yang, X.M.; Sun, L. Residents' Jobs-Residential Locations Migration Paths and Influential Factors of Coal Resource-Based City in the Period of Institutional Transition—A Case Study of Huainan City (1998–2013) in Anhui Province. *Econ. Geogr.* **2015**, *7*, 103–108.
58. Leu, J.; Yen, I.H.; Gansky, S.A.; Walton, E.; Adler, N.E.; Takeuchi, D.T. The association between subjective social status and mental health among Asian im-migrants: Investigating the influence of age at imresidential relocation. *Soc. Sci. Med.* **2008**, *66*, 1152–1164. [CrossRef] [PubMed]
59. Lin, K.C.; Twisk, J.W.R.; Rong, J.R. Longitudinal interrelationships between frequent geographic relocation and personality development: Results from the Amsterdam Growth and Health Longitudinal Study. *Am. J. Orthopsychiatry* **2011**, *81*, 285–292. [CrossRef] [PubMed]
60. Singh, A.L.; Fazal, S.; Azam, F.; Rahman, A. Income, environment and health: A household level study of Aligarh City, India. *Habitat Int.* **1996**, *20*, 77–91. [CrossRef]

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Characteristics and Influencing Factors of Population Migration under Different Population Agglomeration Patterns—A Case Study of Urban Agglomeration in China

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Abstract: China's urban agglomerations (UAs) are striving to build a new development pattern oriented towards the new era and new stage, and the population distribution is facing new problems of synergy with the layout of labor factor productivity and regional coordinated development. Therefore, this study couples UAs with population distribution, using data from three population censuses and nighttime light data in 2000, 2010, and 2020, to measure the population agglomeration patterns of Chinese UAs using population agglomeration indicators and to explore the influencing factors and spatial stratification heterogeneity characteristics by constructing an econometric model. The results show that: (1) the population agglomeration patterns of Chinese UAs can be classified into four major categories: weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs, and China's UAs are in a low-level stage dominated by weakly polycentric UAs at present. (2) In terms of influencing factors, 15 indicators, such as economic development and social conditions, are important factors affecting the population agglomeration patterns of the four UAs, but their effects vary greatly due to specific patterns. (3) For specific agglomeration models, the total passenger volume has always been the strongest positive influencing factor for weakly polycentric UAs; the industry location entropy index, scale of fiscal expenditure, and total passenger volume in municipal districts are relatively strong positive effects to weakly monocentric UAs, the per capita GDP and urbanization rate are relatively strong positive effects to strongly monocentric UAs, and the urbanization rate is always the strongest positive effect to strongly polycentric UAs. The refined analysis of population migration in Chinese UAs in this study enriches the theoretical results related to population migration in Chinese UAs to a certain extent and provides a feasible basis for the development of new development patterns in Chinese UAs and the formulation of regional population policies in the new stage. Meanwhile, this study divided the polycentric attributes of different UAs, which provide a reference for the theoretical development of polycentric spatial structure of UAs.

Keywords: population agglomeration degree; population agglomeration pattern; geographic detector model; urban agglomeration; China

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1. Introduction

As an important region in the world with a high concentration of population, the share of population in urban agglomerations (UAs) has increased from 46.69% in 2000 to 56.15% in 2020 [1] and is expected to reach 68% by 2050 and 85% by 2100 [2]. In addition, the population of the world's top 100 UAs has increased by about 36%, with an average annual growth of about 6.6 million people [3]. The idea of UAs first originated from the concept of "town clusters" proposed by E. Howard (UK) [4], and then Gottmann (France) proposed the concept of "megalopolis" when he analyzed the dense distribution of cities along the northeastern coast of the United States [5]. There are other concepts similar to UAs in Western academia, such as "Desakota" [6] and "Global City Region" [7,8].

Meanwhile, in Chinese academia, Yao Shimou first systematically proposed the concept of UAs [9], and, although scholars have also proposed similar concepts, such as "extended metropolitan regions" [10] and "metropolitan regions" [11], most of the current Chinese geographers use the term "urban agglomeration (UA)" in their studies [12,13]. In China, with the development of the economy, UAs have become important places with the highest concentration and most frequent flow of the Chinese population, so the agglomeration pattern presented by UAs is unique.

Population mobility is usually a process of pursuing individual interests, which makes factors such as economic opportunities, geographical proximity, and environmental conditions in the inflow location important factors influencing population mobility [14]. With the further enhancement of the development imbalance between regions and the gradual relaxation of the household registration system, the dynamism of population mobility in China is increasing [15]. This dynamism is also reflected in relevant studies on population mobility. Not only have some scholars used census data or statistical data, radiation model, social network analysis, and other methods to analyze the population mobility characteristics from a macro perspective [16] but some scholars have also used mobile positioning data and location big data to explore the population mobility characteristics in short time periods [17], while others have used data from mobile population surveys and sampling questionnaires to analyze the population mobility characteristics from a microscopic perspective [18]. Under the influence of factors such as natural environment, economic development, and social conditions, a large number of population movements will have a profound impact on the spatial structure of a region, especially UAs [19]. In terms of studies on the spatial structure of UAs, some scholars have studied the spatial structure and morphology of UAs in terms of the evolution process of the spatial structure of UAs [20]. Some scholars also believe that the formation and development of the spatial structure of UAs is the process of continuous agglomeration of various production factors [21]. The polycentric structure, as an important form of spatial structure of UAs, has gradually attracted the attention of scholars [22]. Some scholars have conducted in-depth exploration on the polycentric spatial structure of UAs using diversified big data [23,24] and believe that the polycentric spatial structure of UAs is conducive to promoting green economic growth [25], and enhancing the economic performance of UAs [26]. However, some scholars believe that the polycentricity of UAs may have certain negative effects [27,28], and the economic benefits generated by UAs in different development stages often show significant differences [29].

Scholars have focused more on the study of polycentric spatial structure at the urban scale [30,31]. There are often several central regions within Chinese cities based on population grid data [32]. The polycentric spatial structure is conducive to promoting the sustainable development of some mega-cities [33]. In terms of the study on polycentric spatial structure and economic performance, some studies suggest that the adjacent agglomerations formed by small-scale cities in a morphological polycentric spatial structure are unable to generate a synergy effect, nor do they have a significant impact on the economic development of central cities [34]. Additionally, the agglomeration of factors such as population and industry in small-scale cities can, to some extent, reduce the negative externalities [35]. However, some scholars believe that polycentric spatial structure may weaken the effect of urban economic growth poles [36], and the efficiency of factor flow decreases due to the increase in commuting distance and transportation costs [37]. In contrast, a monocentric spatial structure with good accessibility can more easily promote economic growth [38], and, therefore, some scholars believe that monocentric spatial structure may be more beneficial to economic performance. In addition, research has also found that a polycentric spatial structure can reduce the intensity of the urban heat island [39], produce a significant pollution reduction effect by affecting the region's PM2.5 [40], and also reduce industrial enterprise pollution emissions by enhancing the mobility of factors [41].

Scholars have gradually explored the demographic characteristics presented by the spatial structure of UAs due to the in-depth exploration on the polycentric spatial struc-

ture [42]. The essence of the urban agglomeration model is to analyze the spatial distribution pattern of population and its evolution trend within the UAs from the perspective of population, and the data used are gradually expanded from the census and statistical data to the dynamic monitoring data of floating population and location big data, and the methods adopted are gradually changed from the statistical methods to the social network analysis methods. It was found that the population distribution in the Tokyo metropolitan area gradually changed from "isolated agglomeration" to "contiguous spreading" [43]. The spatial distribution of the population in the northeastern urban agglomerations of the United States tends to change from unipolar to multipolar, and the spatial structure of the population is both aggregated and dispersed [44]. The distribution structure of employees in the 356 metropolitan areas of the United States indicates that the spatial structure can be divided into three main types: monocentric, polycentric, and decentralized distribution, with the polycentric type located mainly in large cities [45]. The urban areas in central Scotland show polycentric characteristics in terms of morphology [46].

When analyzing the population agglomeration characteristics for regional or national UAs, more Chinese scholars mainly analyze them from a single or several UAs, such as the Yangtze River Delta urban agglomeration (YRD) [47,48] and the Middle Reaches of Yangtze River urban agglomeration (MYZ) [49,50]. The central cities of the YRD urban agglomeration show a tendency of agglomeration and clustering, while the peripheral cities show a tendency of dispersed deviation [51]. The Central Plains urban agglomeration (CPL) evolved from a core growth weak core traction in the early age to the current polycentric grid-based spatial development pattern [52]. The MYZ urban agglomeration has an obvious core–edge trend, showing a "pyramid" structure [53]. In addition, some scholars have analyzed the population agglomeration pattern of Chinese UAs as a whole [54]. It was found that, since the 1980s, most Chinese UAs have formed a polycentric spatial structure [55]. Additionally, based on two indices, the Gini index and the urban primary degree, Chinese UAs can be classified into four categories: strongly monocentric, weakly monocentric, polycentric, and weakly central [56]. The eastern coastal UAs in China exhibit a high degree of polycentricity, while the UAs in the western region generally lack polycentricity [57]. Further, UAs at higher levels of development are mainly located in the eastern coastal regions of China, forming a certain population hierarchy [13]. The UAs of China show an obvious polycentric trend, and different attributes, such as economic level, population size, and transport infrastructure, play a significant positive role in shaping the polycentric nature of UAs [58].

At the same time, with the increase in scholars' study on the population agglomeration patterns in UAs, there has been a gradual increase in the number of studies on the influencing factors of population agglomeration to UAs, which involve the natural environment, economic development, and social conditions [59,60]. It was found that the natural environment is a fundamental factor influencing population distribution and mobility; i.e., changes in the natural environment can enhance population mobility and thus affect the spatial agglomeration pattern of the regional population [61]. Economic development factors, on the other hand, are facilitating factors that influence population agglomeration and spatial distribution, and economic factors can enhance the attractiveness of a population by providing advantages such as higher income levels and more employment opportunities to the population, thus promoting spatial mobility and agglomeration [16,62]. Meanwhile, social conditions factors are guiding factors; social factors such as employment opportunities, expected income levels, and technology drive population spatial agglomeration through their attractiveness to the population [61,63]. In short, UAs attract many populations through a higher degree of opening to the outside world, stronger level of economic development, better-quality public services, and stronger agglomeration scale benefits [64,65]. For UAs in China, economic factors, whose influence is more important than policy factors, are the main factors for higher population mobility within UAs [66]. For example, for the Beijing–Tianjin–Hebei urban agglomeration (BTH), on the one hand, human capital accumulation, industrial structure characteristics, and public service levels

are important factors for long-term population mobility [67]; on the other hand, work and business are still the main factors for short-term population mobility [68].

Existing studies mostly focus on the analysis of population agglomeration patterns of single or several UAs while less on the analysis of population agglomeration patterns of UAs and their evolutionary characteristics from a demographic perspective [52,69]. Additionally, in the process of classifying the types of UAs, although some studies have classified national UAs from demographic data [55] and judged the types of individual UAs from nighttime light data (NTL) and diversity data [70], relatively few studies have been conducted on the correlation between the two. Moreover, in the process of analyzing the factors influencing population agglomeration, existing studies have focused more on the influence of a certain factor on urban population agglomeration and less on the spatial heterogeneity characteristics of the influencing factors, which is not comprehensive [71]. Compared with existing studies, this study does not simply analyze the population migration characteristics under the large scale of Chinese UAs but classifies the types of population agglomeration patterns based on the differentiated characteristics of different UAs and summarizes the general laws of their evolution, which makes this study more in line with the reality of population migration in Chinese UAs. Additionally, based on different population agglomeration patterns, this study analyzes the population migration characteristics of different UAs and their influencing factors, and the findings conclude feasible Chinese experiences for population migration in UAs.

This study aims to investigate the following questions: first, what is the basis for classifying the population agglomeration patterns of UAs in China? Second, from 2000 to 2020, what are the characteristics and evolution rules of population migration in different agglomeration patterns of UAs in China? Third, what are the possible factors influencing the population agglomeration patterns of different UAs, and what are the main differences among them? Compared with existing studies, this study mainly conducts new analysis and discussion on theories, study methods, and data. Firstly, by exploring the internal population flow and agglomeration characteristics of different population agglomeration attributes in UAs, the study to some extent enriches the theoretical and practical achievements of population migration in UAs and the polycentric spatial structure of UAs. Secondly, by using two dimensions, population agglomeration degree and population primacy degree, to divide the population agglomeration pattern of UAs, this study makes the results of population migration in large-scale UAs in China more credible. Finally, by using the geographical detector model, the spatially stratified heterogeneous characteristics of the influencing factors are obtained. This study hopes to provide a reference for the development of new urbanization in Chinese UAs and the formulation of regional population policies.

2. Materials and Methods

The research framework contains three main sections. The first part reveals the characteristics of population agglomeration in China's UAs from the aspects of population agglomeration degree, population primacy degree, and net migration rate. The second part first obtains the classification of population agglomeration patterns of UAs and classifies China's 19 UAs into 4 categories: weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs. Secondly, this study provides an analysis of the population migration characteristics presented by different urban agglomeration patterns. Then, this study comprehensively considers the influencing factors of population agglomeration from the factors of both economic development and social conditions and uses the geographical detector model to obtain the spatial stratified heterogeneity characteristics of influencing factors. The third part summarizes the evolution law of population agglomeration patterns in China's UAs based on population data and compares and evaluates the types of UAs obtained from NTL data. The working flowchart is as follows (Figure 1).

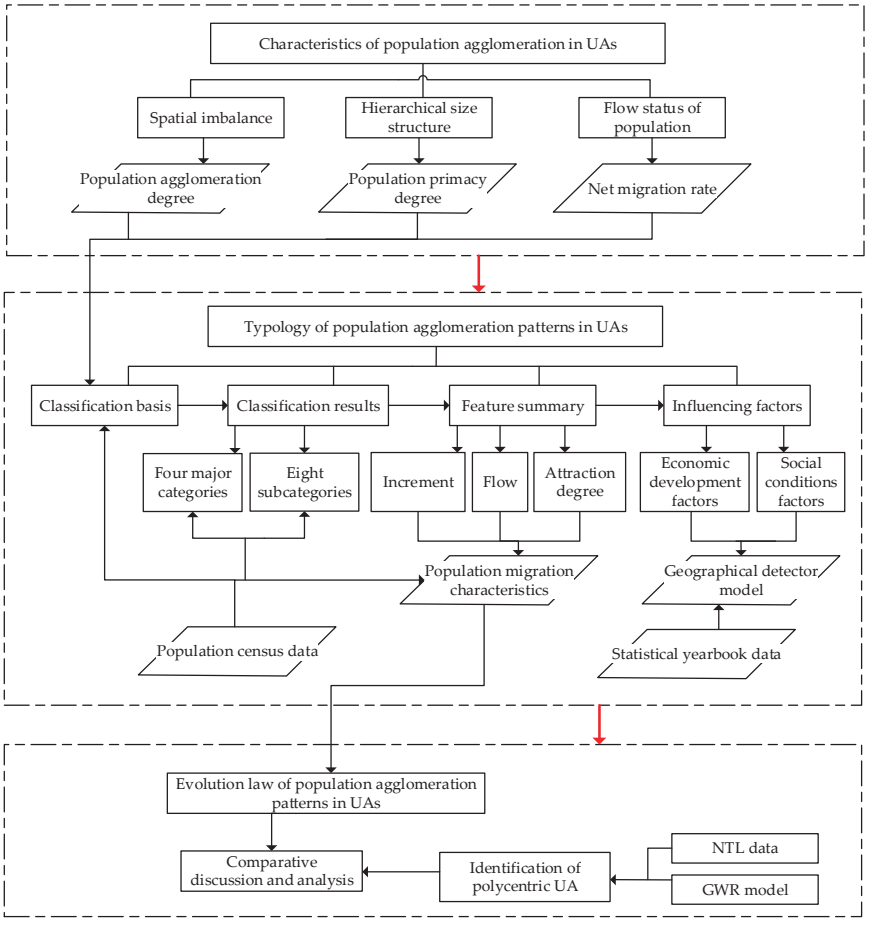


Figure 1. Working Flowchart.

2.1. Study Area

The scope of the 19 UAs in China is mainly derived from the thirteenth five-year plan (from 2016 to 2020) [72]. In 2020, the number of cities involved in the 19 UAs is 257, accounting for about 40% of the total number of cities in China; their GDP, on the other hand, accounts for about 85% of the total GDP of all Chinese cities [73]. The population agglomeration degree of 19 UAs has increased from 2.57 in 2000 to 2.70 in 2020, and the total number of permanent residents increased from 901.95 million to 1069.88 million; meanwhile, the net migration rate of the population in UAs has also increased from 2.68% in 2000 to 5.50% in 2020, which indicates that the UAs are important places with large populations, rapid growth, and net population inflow in China. The UAs, with their strong economic development strength, have stronger attraction to the population than outside UAs. From 2000 to 2020, the YRD, PRD, and BTH UAs have higher permanent population growth, with a growth scale of 43.44 million, 35.07 million, and 20.27 million, respectively, accounting for 58.82% of the total growth scale of UAs in the same period [74,75]. Additionally, according to the development level of the 19 UAs in China in 2010, they can be classified into four development types, namely Low level, Low-middle level, Upper-middle level, and High level UAs [13] (Figure 2).

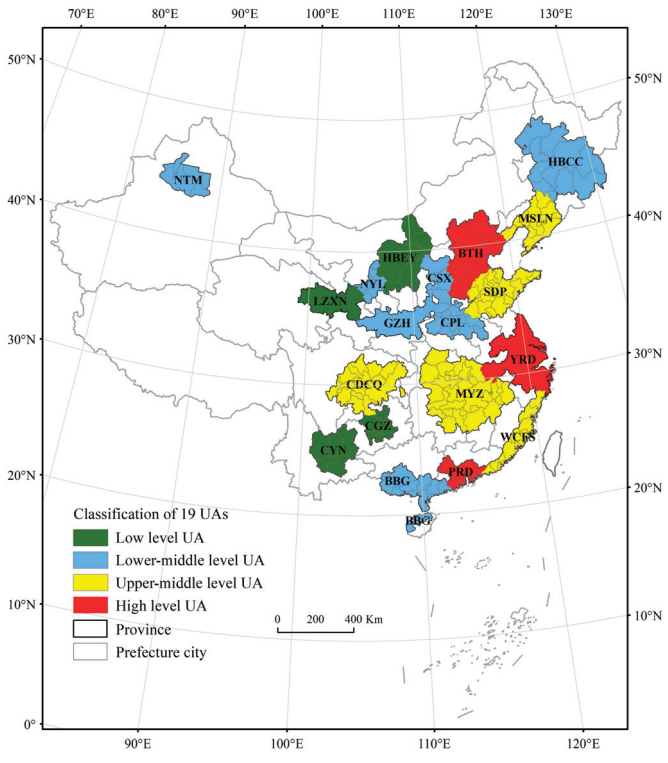


Figure 2. Spatial Scope of 19 UAs in China. Note: original source is from the Standard Map Service website (http://bzdt.ch.mnr.gov.cn/, accessed on 25 September 2021), Number: GS (2019) 1699.

2.2. Data Sources

The sources of demographic data, economy, vector layer, NTL, and other data are shown in Table 1. Among them, the economic data are selected from the China City Statistical Yearbook in 2001, 2011, and in 2021; the main reason for such selection is because they reflect the economic development of the previous year, which is more consistent with the years of the fifth, sixth, and seventh census data. In addition, the administrative divisions used in the vector layers uniformly use the 2010 division results.

Table 1. Data Sources.

Type	Data Sources	Accessed Date	Acquisition Websites
Demographic Data	Tabulation on the Population Census of the People's Republic of China by County(2000, 2010, 2020)	15 September 2021	http://www.stats.gov.cn/ (accessed on 25 September 2021) [74,75]
Economic Data	China City Statistical Yearbook (2001, 2011, 2021)	1 September 2021	https://data.cnki.net/yearBook/ (accessed on 25 September 2021) [73]
Vector Layer	Resource and Environmental Data Center	25 September 2021	http://www.resdc.cn/ (accessed on 25 September 2021)
NTL Data	The National Center for Environmental Information (NCEI) of National Oceanic and Atmospheric Administration (NOAA) (2000, 2010, 2020)	5 September 2021	https://eogdata.mines.edu/products/vnl/ (accessed on 25 September 2021)

2.3. Index System

The spatial agglomeration and flow of population is a dynamic process, and its influencing factors often involve natural environment, economic development, social conditions, and policies. The natural environment, a fundamental factor, mainly affects the flow and

spatial agglomeration of population through geographical location, altitude, temperature, precipitation, and other factors [59]. Many scholars have explored the correlation between natural environmental factors and population distribution and flow through qualitative analysis, and research showed that the impact of natural environmental factors is gradually declining [61]. In addition, economic development factors and social condition factors, as important pulling forces for population spatial agglomeration and flow, have increasingly increased their impact on population [16].

As the main factor influencing population migration, the spatial migration of population is mainly for economic development factors, such as access to higher wages, more employment opportunities, higher economic status, etc. [76,77]. Economic differences between regions drive population movement and concentration from less developed regions to economically developed regions, mainly because, first, cities with higher levels of economic development tend to offer higher labor compensation, more employment opportunities, etc. Second, the higher the degree of regional economic development, the greater the demand for various factors, such as capital, technology, and personnel, which facilitates the free flow of various factor resources and thus creates a stronger attraction for the population [78,79]. Third, the optimization and upgrading of industrial structure also attracts the cross-regional mobility of labor by providing more jobs, which makes the population of the region change [80]. Fourth, a convenient transportation system can bring closer the intensity of connections among cities, as well as the intra-city movement of various factors, thus reducing production and commuting costs, which in turn has an important impact on the spatial agglomeration of population in the region [81,82]. In addition, as the scale of financial expenditures that cities can provide increases, the level of public service capacity spent on public services also increases, which is conducive to enhancing the attractiveness of people with different needs, such as schooling and medical care [83], and the ability to provide higher quality public services, higher levels of openness, and a good living environment are likely to be attractive to the population [84,85]. The cities with high urbanization rates also attract a large inflow of population and increase the level of population agglomeration through policy preferences and other measures [86]. Compared with existing studies, this study mainly focuses on economic development and social condition factors (Table 2).

Table 2. Influencing Factor Index System.

Factors	Name of Indicator (Abbreviation)	Representational Meaning	References
economic development factors	per capita GDP (PerGDP)	reflecting the regional economic development degree	[62,85]
	Proportion of tertiary industry in GDP (Ind)	reflecting the urban industrial modernization level	[67,76]
	Investment scale of fixed assets (Fai)	reflecting the urban economic development vitality	[78]
	Total passenger volume (Tpv)	reflecting the convenience of personal mobility ability of other cities outside the city	[65,82]
	Total freight volume (Tfv)	reflecting the convenience of goods mobility ability of other cities outside the city	[82]
	Total passenger volume in municipal districts (Tpvmd)	reflecting the convenience of personal mobility ability within the city	[81]
	Industry location entropy index (Ilei)	reflecting the urban employment structure	[13]
	Growth index of enterprise structure above Designated Size (Gies)	reflecting the economic development vitality of urban industrial subjects	[13]
social conditions factors	Scale of fiscal expenditure (Exp)	reflecting the ability to provide urban public services and infrastructure	[82]
	Average wage of on-the-job employees (Wag)	reflecting the urban average wage level	[63,66]
	Teacher–student ratio in primary and secondary schools (Edu)	reflecting the ability to provide education resources	[80,85]
	Number of beds in welfare institutions per ten thousand people (Wel)	reflecting the ability to provide medical service	[67,82]
	Standard rate of industrial wastewater treatment (Iwt)	reflecting the urban production environment conditions	[82]
	Greening coverage rate of built-up area (Gcr)	reflecting the urban living environment conditions	[84,85]
	Urbanization rate (Urb)	reflecting the population migration degree to city	[76,86]

2.4. Study Methods

2.4.1. Measuring of Population Agglomeration Patterns in UAs

(1) Net Migration Rate

The net migration rate of the population can clearly reflect the inflow or outflow status of the population in the region and thus identify the net inflow population area or net outflow population area [87]. The calculation formula is provided in Equation (1).

$$NM = (P_{permanent} - P_{registered})/P_{permanent} \times 100\% \quad (1)$$

where NM is the net migration rate of population, $P_{permanent}$ is the permanent population, and $P_{registered}$ is the registered population. When NM value is positive, it indicates that the population is flowing into the area, forming a net inflow population area; conversely, it forms a net outflow population area.

(2) Population Agglomeration Degree

Population agglomeration degree refers to the ratio of regional population density to the population density of China in the current year, which can clearly reflect the degree of population agglomeration of a region relative to the population of China [88]. The calculation formula is provided in Equation (2).

$$JJD_i = \frac{(P_i/P_n) \times 100\%}{(A_i/A_n) \times 100\%} = \frac{P_i/A_i}{P_n/A_n} \quad (2)$$

where JJD_i is the population agglomeration degree of region i, P_i and A_i are the population number and land area of region i, respectively, and P_n and A_n are the total population and land area of China, respectively.

(3) Population Primacy Degree

Population primacy degree is the degree of variability between primary city and secondary city, which can clearly reflect the hierarchical size structure of population distribution [89,90]. The calculation formula is provided in Equation (3).

$$Q = \frac{P_1}{P_2} \quad (3)$$

where Q is the population primacy degree, P_1 and P_2 are the population size of the primary city and the secondary city, respectively.

2.4.2. Measuring of Factors Influencing Population Agglomeration Degree in UAs

(1) Linear regression model

This study selects the population agglomeration degree (JJD) of the city as the dependent variable and 15 indicators to be tested as independent variables and constructs linear regression model to explore the factors that affect the population agglomeration degree of UAs. The population primacy degree reflects the hierarchical size structure of population distribution and the population gap characteristics between the first city and the second city, which is not as significant as the population agglomeration degree index on characterizing the significance of population agglomeration. The calculation formula is provided in Equation (4).

$$\begin{aligned} JJD = \beta + \beta_1\, perGDP + \beta_2\, ind + \beta_3\, fai + \beta_4\, tpv + \beta_5\, tfv + \beta_6\, tpvmd + \beta_7\, ilei + \beta_8\, gies + \beta_9\, exp + \beta_{10}\, wag + \beta_{11}\, edu \\ + \beta_{12}\, wel + \beta_{13}\, iwt + \beta_{14}\, gcr + \beta_{15}\, urb + \xi, \end{aligned} \quad (4)$$

where β, β_1, β_2, ... , β_{15} are parameters to be estimated, JJD is the population agglomeration degree. The meaning of indicators to be tested is shown in Table 2. ξ is a random disturbance term obeying normal distribution. Subsequently, this study takes the indicators that significantly affect JJD as independent variables of the geographical detector

model and further explores the spatial stratification heterogeneity characteristics of the influencing factors.

(2) Geographical detector model

The geographical detector model was initially used to explore the geographical relationship between disease causes and disease distribution and was used to explore the spatial heterogeneity of the effects of influencing factors by using the advantages in spatial regression [91,92]. This study uses geographical detector model to explore the spatial stratification heterogeneity characteristics of influencing factors in UAs. Specifically, the population agglomeration degree is dependent variable and 15 variables that have a significant impact on JJD in the linear regression model are selected as independent variables. The calculation formula is provided in Equation (5).

$$q = 1 - \frac{1}{N\sigma^2} \sum_{m=1}^{L} N_m \sigma_m^2 \tag{5}$$

where q is the explanatory power of regional geographic environmental factors, $m = 1, 2, \ldots, L$ is the number of categories, N_m and N are the number of layer m and the number of cells in the whole region, respectively, σ^2 is the variance of the indicator. Further, values range from 0 to 1, and larger q values indicate stronger explanatory power of spatial heterogeneity.

3. Results

3.1. Typology of Population Agglomeration Patterns in UAs

3.1.1. Evolution Characteristics of Population Agglomeration in UAs

The change in population agglomeration degree reflects that China's population is more concentrated in UAs with higher levels of economic development. Overall, population agglomeration degree shows a positive correlation with the development degree of UAs; that is, the higher the development degree of UAs, the more attractive they are to the population and the higher the population agglomeration degree. From 2000 to 2020, the share of permanent population in Low level, Low-middle level, Upper-middle level, and High level UAs evolves from 4.31%, 16.45%, 31.33%, and 20.49% in 2000 to 4.61%, 16.18%, 30.03%, and 25.07% in 2020, respectively, with the High level UAs increase of 4.58%, which indicates that the attractiveness of such UAs to the population is increasing. In addition, from 2000 to 2020, only the total permanent population of the Harbin–Changchun urban agglomeration (HBCC) decreases by −3.66 million, while the other 18 UAs show an increase in the total permanent population, with the Pearl River Delta (PRD) and the YRD urban agglomerations ranking the top two, with an increase of 2.08% and 1.92% of the share of the permanent population, respectively (Figure 3).

The change in the degree of population primacy reflects the increasing unevenness of population distribution in most UAs in China. This is not only related to the total existing population and the average annual growth rate of population in cities of different size classes within UAs but is also related to the increase in the number of population in the primary city due to the change in the administrative division of cities; it is related to the fact that some provinces are promoting the development strategy of provincial capital cities one after another as well so as to attract a large population. From 2000 to 2020, among the nineteen UAs, the population primacy degree of twelve UAs shows an increasing trend, and six UAs show a decreasing trend. Additionally, in the three time periods from 2000 to 2010, from 2010 to 2020, and from 2000 to 2020, the population primacy degree of eight UAs, mostly belonging to the less developed UAs (the Beibu Gulf (BBG), Central Yunnan (CYN), Guanzhong Plain (GZH), Central Shanxi (CSX), Lanzhou–Xining (LZXN), Ningxia Yellow River (NYL), Northern Tianshan Mountains (NTM), and BTH urban agglomeration), continues to increase, while the population primacy degree of four UAs, mostly belonging to the more developed UAs (Chengdu–Chongqing (CDCQ), Hohhot–Baotou–Ordos–Yulin

(HBEY), Shandong Peninsula (SDP), and PRD urban agglomeration), continues to decrease (Figure 3).

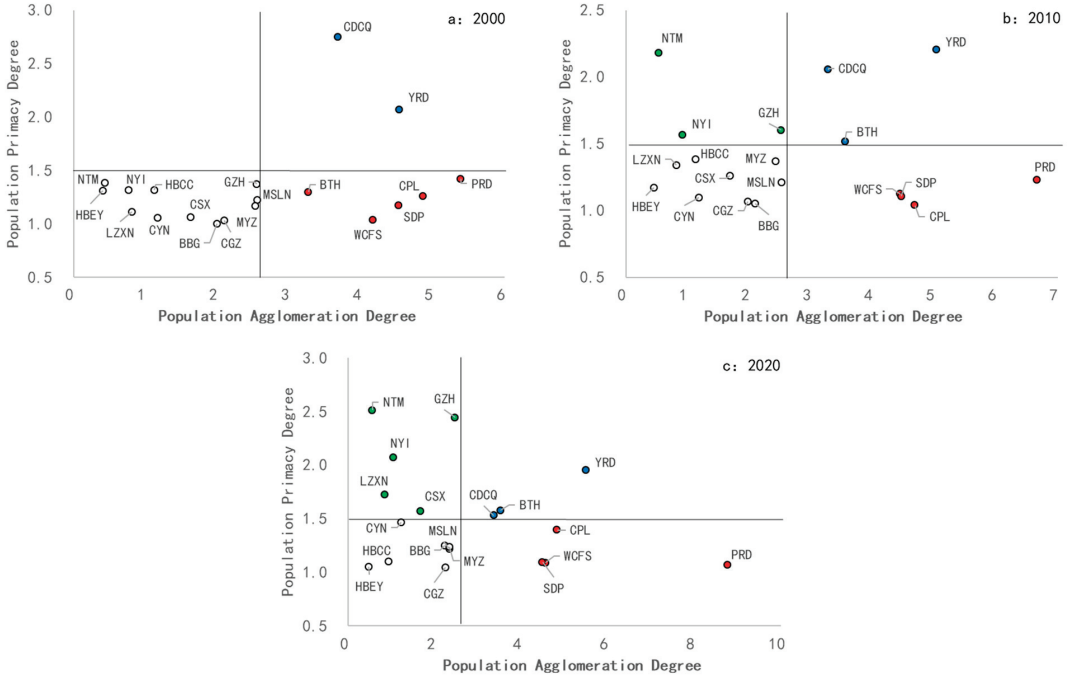


Figure 3. Evolution Characteristics of Population Agglomeration Degree and Population Primacy Degree of UAs in China from 2000 to 2020 ((**a**): 2000; (**b**): 2010; (**c**): 2020).

3.1.2. Classification Results of Population Agglomeration Patterns in Different UAs

The classification of population agglomeration pattern of UAs is mainly achieved by the two indices, namely population agglomeration degree and population primacy degree. On the one hand, UAs can be classified into strong population agglomeration and weak population agglomeration according to the level of population agglomeration degree. On the other hand, UAs can be classified into monocentric and polycentric according to the level of population primacy degree, and then can be further classified into four major categories, weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs (Figure 4), among which weakly polycentric UAs means that the UAs have both a low population agglomeration and a low population primacy, while weakly monocentric UAs means the UAs have low population agglomeration but high population primacy. Strongly monocentric UAs means that the UAs have both a high population agglomeration and a high population primacy, while strongly polycentric UAs means that the UAs have a high population agglomeration but a low population primacy. From 2000 to 2020, the population agglomeration degree of 19 UAs in China mainly ranges from 1 to 3, while the population primacy degree mainly ranges from 1 to 2. Therefore, this study extracts 2.6 and 1.5 as the boundary values of population agglomeration degree and population primacy degree, respectively, to determine the types of population agglomeration patterns of UAs.

The four major categories of urban agglomeration patterns are then continued to be divided into eight subcategories based on the net population inflow or outflow status presented by the UAs as a whole, mainly using the CorelDRAW software to present the schematic diagram of population migration (Figure 5).

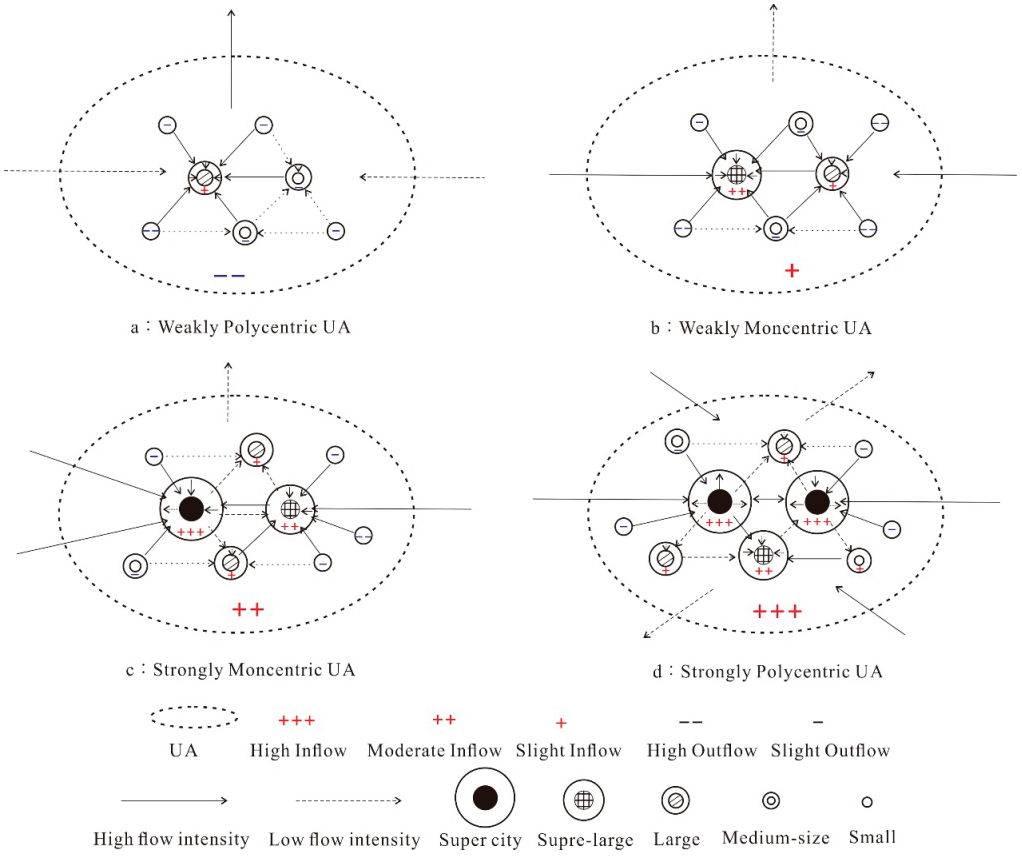


Figure 4. Four Major Categories of Population Agglomeration Patterns in Chinese UAs. Note: cities are divided into five levels based on their permanent resident population, including Super city, Super-large city, Large city, Medium-sized city, and Small cities. "+" is used to represent population inflow state, and, the more "+" signs there are, the greater the degree of population inflow. "−" represents population outflow state, and, the more "−" signs there are, the more severe the degree of population outflow. Arrows represent the direction and intensity of population mobility, with solid lines indicating a higher flow intensity and dotted lines indicating a lower flow intensity.

Currently, China's UAs are in a low-level stage dominated by weakly polycentric UAs. Overall, the evolution of population agglomeration patterns of UAs at different time points from 2000 to 2020 indicates that the number of UAs with different population agglomeration patterns in China is gradually equalized. Specifically, from 2000 to 2010, there are four UAs whose population agglomeration patterns change, among which the GZH, NYL, and NTM urban agglomerations change from weakly polycentric to weakly monocentric while the BTH urban agglomeration changes from strongly polycentric to strongly monocentric. Meanwhile, from 2010 to 2020, there are only two UAs whose population agglomeration patterns change, of which both LZXN and CSX urban agglomerations change from weakly polycentric to weakly monocentric. The main reason for such results is the increasing attractiveness of the primary city to the population, which leads to the enlargement of the population primary degree. Therefore, this study uniformly analyzes the population migration characteristics presented by the population agglomeration patterns of UAs according to the results of the agglomeration pattern classification in 2020 (Table 3).

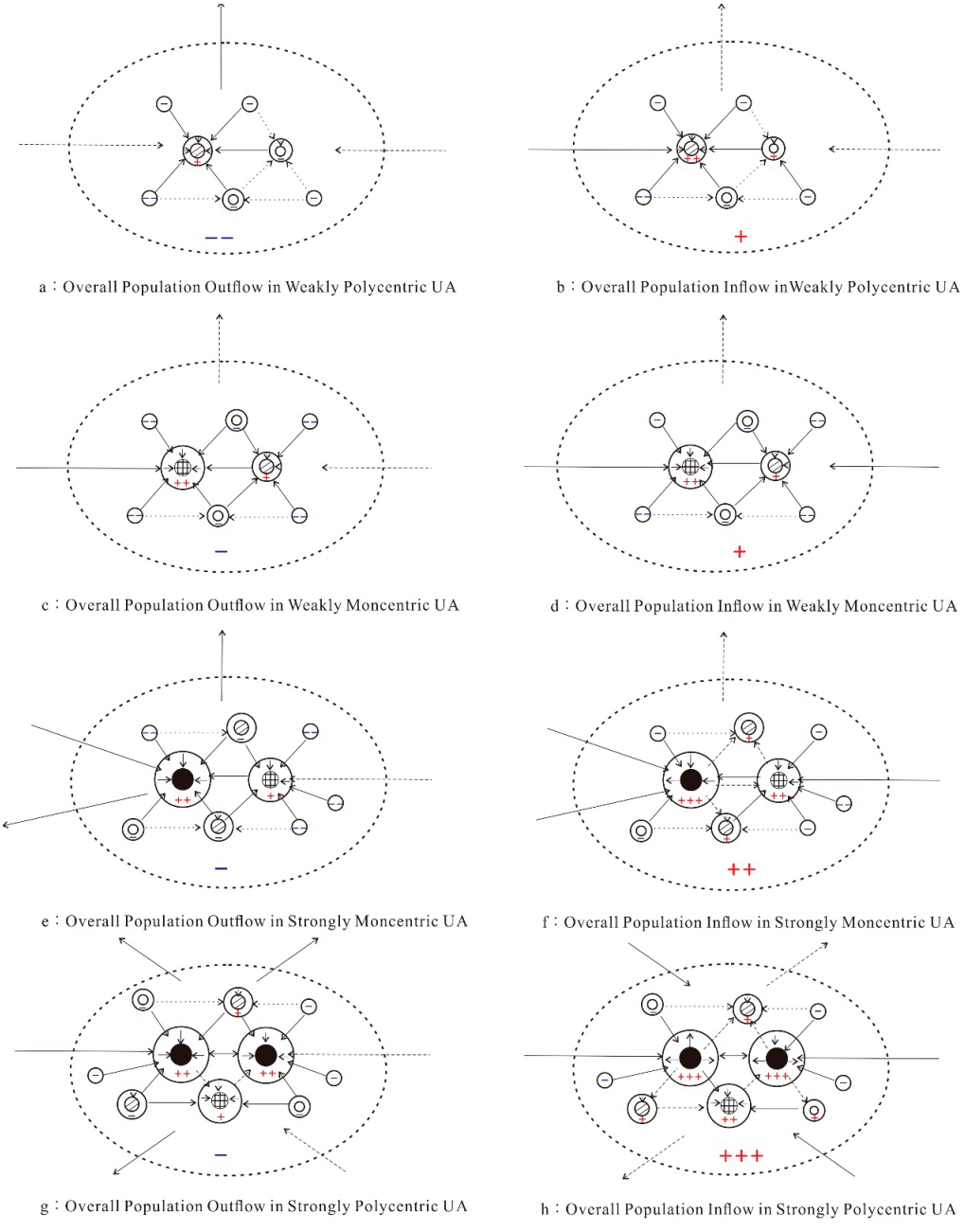


Figure 5. Population Migration of Different Urban Agglomeration Patterns in China.

Table 3. Classification Results of Population Agglomeration Patterns of UAs in China from 2000 to 2020.

Type	Name		
	2000	2010	2020
Weakly Polycentric UAs	CYN, BBG, MYZ, CGZ, HBCC, GZH, NYI, HBEY, CSX, MSLN, NTM, LZXN (n = 12)	CYN, BBG, MYZ, CGZ, HBCC, HBEY, CSX, MSLN, LZXN (n = 9)	CYN, BBG, MYZ, CGZ, HBCC, HBEY, MSLN (n = 7)
Weakly Moncentric UAs		NTM, GZH, NYI (n = 3)	LZXN, NTM, GZH, NYI, CSX (n = 5)
Strongly Moncentric UAs	CDCQ, YRD (n = 2)	CDCQ, YRD, BTH (n = 3)	CDCQ, YRD, BTH (n = 3)
Strongly Polycentric UAs	WCFS, SDP, CPL, PRD, BTH (n = 5)	WCFS, SDP, CPL, PRD (n = 4)	WCFS, SDP, CPL, PRD (n = 4)

3.2. Population Migration Characteristics of UAs with Different Population Agglomeration Types

3.2.1. Population Migration Characteristics of Weakly Polycentric UAs

Generally speaking, such UAs have a low degree of population agglomeration, a small total population, and a low degree of population primacy. The main manifestations are as follows: first, intra-provincial in-migrants are the major part of the inflow population, while the inter-provincial in-migrants are small and concentrated in the municipal districts of central cities. Second, although the natural population growth rate is at a high level, UAs are less attractive to the population. Additionally, the central cities have a high inflow of population in their municipal districts, while the surrounding districts and counties have a high outflow of population (Table 4). Such UAs can be divided into two subcategories.

Table 4. Population Migration Characteristics of Population Agglomeration Patterns in UAs.

Characteristics	Weakly Polycentric UAs	Weakly Moncentric UAs	Strongly Moncentric UAs	Strongly Polycentric UAs
Population agglomeration degree	low	lower	higher	high
Total population	small	larger	large	large
Population primacy degree	low	higher	high	lower
Population increment	The population increment of central cities is larger while the polarization effect is weaker	The primary city is experiencing more population growth and the polarization effect is increasing	The population growth of the central cities is large, and the polarization effect is more prominent	Large incremental growth in central cities, narrowing the gap with the primary city and increasing the trickle-down effect
Total in-migrant population	low	lower	higher	higher
Population attraction degree	weaker	weaker, but improving	stronger	strong
Population outflow	The inflow of population is large in the municipal districts of central cities, while the outflow of population is large in the surrounding counties.	The inflow of population in the municipal district of the central city is large, the inflow of population in the municipal district of the general city is small, and the majority of the county area shows a large outflow of population.	Both the municipal districts of the central cities and the surrounding counties show a large inflow of population; the municipal districts of the general cities show a large inflow of population, while the surrounding counties mostly show a large outflow of population	The central cities have high population inflows in their municipal districts and surrounding counties have lower population outflows
Natural population growth rate	high	higher	lower	lower

One subcategory is the UAs in an overall state of population outflow, which is manifested by a high net emigration rate of population. First, the incremental permanent population in the central cities is higher while the incremental population in other cities is lower and the polarization effect is weaker. Second, the population is mainly concentrated in the core cities, with natural population growth being the main reason for the increase in the total population of UAs. Therefore, districts and counties with high population outflow

and high population inflow are the main types. This type is applicable to the BBG, Central Guizhou (CGZ), and MYZ urban agglomerations (Figure 5a).

The other subcategory is the UAs in an overall state of population inflow, which is manifested by a low net in-migration rate of population. First, there is a significant increase in permanent population in the central cities and a stronger increase in other cities, as well as cities with negative population growth, and a polarization effect is formed. Second, the population flows mainly to the central cities, as well as to the municipal districts of other cities. Additionally, the population increase in UAs is mainly influenced by the higher natural population growth rate, as well as the higher population inflow within the UAs, while most of the districts and counties continue to have population outflow. This type is applicable to the HBEY, HBCC, CYN, and Mid-southern Liaoning (MSLN) urban agglomerations (Figure 5b).

3.2.2. Population Migration Characteristics of Weakly Monocentric UAs

Generally speaking, such UAs have a low degree of population agglomeration and an increase in total population. The main manifestations are, first, the gap between the primary city and the secondary city is gradually widening, and the polarization effect is increasing. Second, although the population increase in central cities is more obvious and the amount of inter-provincial in-migration has slightly increased, it is still concentrated in the municipal districts of central cities. Third, although the attractiveness of UAs to the population is still weak, it has improved. Fourth, the natural population growth rate has increased, with higher natural population growth being the main reason for the increase in the total population of UAs. Additionally, the central city has a large inflow of population in its municipal district, the general city has a slight inflow of population in its municipal district, while the county mostly shows a large outflow of population (Table 4). Such UAs can be divided into two subcategories.

One subcategory is the UAs in an overall state of population outflow, which is manifested by a low net emigration rate but an increasing net emigration of the population. Intra-provincial in-migration is an important mainstay of in-migration in UAs, with high population outflow from districts and counties as the main type. It applies to the GZH urban agglomeration (Figure 5c).

The other subcategory is the UAs in an overall state of population inflow, which shows a predominant net in-migration of population. Districts and counties with high population inflow and high population outflow are the main types of such UAs. The intra-provincial in-migration is the important mainstay of in-migration in UAs, while the population inflow rate is low, which applies to NYL, CSX, and LZXN urban agglomerations. The more special one is the NTM urban agglomeration; the inter-provincial in-migration population is an important mainstay of the in-migration population of the UAs, with a high population inflow rate (Figure 5d).

3.2.3. Population Migration Characteristics of Strongly Monocentric UAs

Generally speaking, such UAs have a high and continuously increasing population agglomeration degree, and the population scale further increases. The main manifestations are, first, the gap between the primary city and the secondary city is greater, and the polarization effect is more pronounced. Second, central cities are still the regions with the most obvious increase in permanent population, and, although the scale of inter-provincial in-migration has further increased, it is still concentrated in central cities. Third, although the attractiveness of UAs to the population has further increased, the natural population growth rate is at a low level, and districts and counties with negative natural population growth rates have started to appear (Table 4). Such UAs can be divided into two subcategories.

One subcategory is the UAs in an overall state of population outflow, the main manifestations of which are as follows: first, the central city has a large inflow of population in its municipal district, the general city has a slight inflow of population in its munici-

pal district, while the county mostly shows a large outflow of population. Additionally, intra-provincial in-migration is an important mainstay of in-migration in UAs. Therefore, districts and counties with high population outflow are the main types, such as the CDCQ urban agglomeration (Figure 5e).

The other subcategory is the UAs in an overall state of population inflow, the main manifestations of which are as follows: first, both the municipal districts of the central cities and the surrounding counties exhibit significant population inflows. The general city has a large inflow of population in its municipal district, while the county mostly shows a large outflow of population. Second, inter-provincial in-migration is gradually becoming an important part of in-migration in UAs. Therefore, districts and counties with high population inflow are the main types of such UAs. Meanwhile, it is noteworthy that the municipal districts of the central cities show a trend of population migration to the surrounding districts and counties, and the trickle-down effect of the central cities is increasing, such as the BTH and YRD urban agglomerations (Figure 5f).

3.2.4. Population Migration Characteristics of Strongly Polycentric UAs

Generally speaking, such UAs have a high degree of population agglomeration with a large total population. The main manifestations are, first, several central cities are formed within the UAs, and the gap with the primary city is gradually narrowing, and the degree of population primacy is low. Second, although the UAs are more attractive to the population, the natural population growth rate is at a low level (Table 4). Such UAs can be divided into two subcategories.

One subcategory is the UAs in an overall state of population outflow. The main manifestations are, first, intra-provincial in-migration is an important part of the in-migration of UAs. Second, with the increasing polarization effect of central cities, the municipal districts of central cities have high population inflow, while the surrounding districts and counties have population outflow, and, the farther away from the municipal districts, the higher the degree of population outflow. Therefore, districts and counties with high population outflow and central cities with weak trickle-down effect are the main types, such as the CPL urban agglomeration (Figure 5g).

The other subcategory Is the UAs In an overall state of population Inflow. First, the population of the central city flows from the municipal districts to the surrounding districts and counties. Second, while the polarization effect of the central city is enhanced, its trickle-down effect is also enhanced, and all other cities within the UAs show an increase in permanent population. Thus, the intra-provincial in-migration is still the mainstay of the in-migration population in UAs, and the districts and counties with high population outflow and high population inflow are the main types, but, overall, the population inflow rate is still low, such as the West Bank of the Taiwan Strait (WCFS) and SDP urban agglomerations. A special case is the PRD urban agglomeration, where inter-provincial in-migration is an important mainstay of in-migration and is relatively scattered in all cities of the UAs. Districts and counties with high population inflow are the main types, with high population inflow rate on the whole (Figure 5h).

The study finds that the evolution of population agglomeration patterns In Chinese UAs has distinctive periodic and regional characteristics. By analyzing the population agglomeration patterns of 19 UAs in 2000, 2010, and 2020, these UAs are considered to proceed through the evolution patterns of weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs (Figure 4). It should be noted that, for the three main types of weakly monocentric, strongly monocentric, and strongly polycentric UAs, the type that presents an overall positive net migration rate of the population of the UAs is the main form in its subcategories. Additionally, by comparing the population characteristics of different UAs at the same point in time and the population characteristics of the same UAs at different points in time, this study finds that the four patterns have different characteristics. First, the population of the weakly polycentric UAs is characterized by "agglomeration in outflow", with a high degree of population outflow. Second, weakly

monocentric UAs show "absolute concentration", with an overall population inflow, but the inflow is concentrated in the central cities, while many cities lose population. Third, strongly monocentric UAs show "relative concentration", with an overall increase in population inflow but still with more population in the central cities. Finally, strongly polycentric UAs show a "relatively decentralized" characteristic, with a higher overall population inflow and a higher population inflow to other cities besides the central cities, and the trickle-down effect of the central cities to other cities is also increasing.

3.3. Analysis on the Influencing Factors of Population Migration in UAs of Different Population Agglomeration Types

Firstly, the linear regression model shows that there is no collinearity among the 15 indicators to be tested, and they all significantly affect the population agglomeration degree at the level of 5% (Table 5).

Table 5. Linear Regression Model Results of Population Agglomeration Degree of UAs (from 2000 to 2020).

Indicators	Coefficient (t Statistic)			VIF		
	2000	2010	2020	2000	2010	2020
PerGDP	0.213 (1.301)	−0.465 *** (−2.623)	0.106 (0.555)	7.92	7.71	5.02
Ind	0.394 (1.505)	0.083 (0.354)	1.734 *** (4.710)	2.38	2.44	2.33
Fai	−0.281 *** (−2.807)	−0.012 (−0.091)	−0.269 ** (−2.441)	5.16	7.11	5.49
Tpv	0.098 (1.276)	0.255 *** (3.390)	0.056 (0.937)	2.48	3.19	2.11
Tfv	−0.055 (−0.617)	−0.053 (−0.655)	0.006 (0.085)	3.42	2.83	2.38
Tpvmd	0.001 (0.025)	0.003 (0.073)	0.043 (0.645)	3.96	3.31	4.69
Ilei	0.232 ** (2.600)	0.183 *** (2.828)	0.406 *** (5.391)	5.24	3.54	4.47
Gies	0.192 * (1.937)	0.456 *** (4.396)	0.409 *** (4.167)	8.68	6.92	5.36
Exp	0.190 ** (2.156)	−0.437 *** (−2.702)	−0.344 ** (−2.248)	5.56	9.16	8.27
Wag	0.124 (0.478)	0.415 (1.385)	−0.108 (−0.310)	3.39	3.39	3.1
Edu	−0.548 ** (−2.513)	−0.828 *** (−3.230)	−0.802 ** (−2.580)	2.76	1.47	1.44
Wel	−0.589 *** (−3.150)	−0.482 ** (−2.562)	−0.602 *** (−2.745)	3.16	1.86	1.89
Iwt	0.146 * (1.738)	0.078 (0.591)	−0.056 (−0.103)	1.23	1.31	1.12
Gcr	0.035 (0.360)	−0.066 (−0.619)	0.246 (0.536)	1.5	1.28	1.5
Urb	−0.001 (−0.005)	1.077 *** (3.710)	0.398 (1.022)	5.24	5.54	4.05

Note: *, **, and *** represent significance level at 10%, 5%, and 1%, respectively. VIF value is used to test the collinearity of variables.

Secondly, the geographical detector model shows that the explanatory power of spatial stratified heterogeneity (q statistics) of various influencing factors on population agglomeration degree is strong (Table 6). The results are as follows:

(1) For the weakly polycentric UAs, only two influencing factors have weakened explanatory power, namely the growth index of enterprise structure above designated size (*Gies*) and the greening coverage rate of built-up area (*Gcr*). From 2000 to 2020, the explanatory power of total passenger volume (*Tpv*) on the spatial distribution of population agglomeration has always been the strongest, with the explanatory power of 2000, 2010, and 2020 being 0.223, 0.200, and 0.233, respectively, and passing the significance test at the 5% level. For cities in weak polycentric UAs, the inner cities tend to have relatively lower levels of economic development, weaker polarization effects of the central cities, and relatively limited attractiveness to the population, while high total passenger volume means a more convenient transportation network and stronger population mobility, which is conducive to enhancing the cities' attractiveness to population agglomeration.

(2) For the weakly monocentric UAs, although there are two influential factors with weakened explanatory power, namely average wage of on-the-job employees (*Wag*) and the standard rate of industrial wastewater treatment (*Iwt*), the explanatory power of industry location entropy index (*Ilei*), scale of fiscal expenditure (*Exp*), and total

passenger volume in municipal districts (*Tpvmd*) on the spatial distribution of population agglomeration are always relatively strong from 2000 to 2020, among which the explanatory power of *Ilei* is 0.434, 0.501, and 0.554 in 2000, 2010, and 2020, respectively, and passes the significance test at the 5% level. The explanatory power of *Tpvmd* is 0.333, 0.479, and 0.596 in 2000, 2010, and 2020, respectively, and passes the significance test at the 5% level. Meanwhile, the explanatory power of *Exp* is 0.485 and 0.586 in 2010 and 2020, respectively, and passes the significance test at the 5% level. For cities in weakly monocentric UAs, their ability to provide more alternative employment opportunities and better-quality public services will attract more mobile people to work and live in the city and enjoy the various services it offers. At the same time, closer intra-city transportation links not only indicate greater population mobility but also contribute to lower commuting costs and higher levels of population agglomeration.

(3) For the strongly monocentric UAs, although there are three influencing factors with weaker explanatory power, namely per capita GDP (*PerGDP*), teacher–student ratio in primary and secondary schools (*Edu*), and the number of beds in welfare institutions per ten thousand people (*Wel*), overall, the explanatory power of *PerGDP* and urbanization rate (*Urb*) on the spatial distribution of population agglomeration is still stronger from 2000 to 2020, with explanatory power evolving from 0.424 and 0.346 in 2000 and 0.494 and 0.420 in 2010 to 0.417 and 0.518 in 2020 and passing the significance test at the 1% level. For cities in strongly monocentric UAs, higher GDP per capita means higher level of economic development, higher demand for labor and population, and relatively higher level of labor wages that can be provided to meet the consumption needs of the population in the city, which can easily attract the population. Meanwhile, cities with higher urbanization rates also usually have higher levels of economic development, which is more attractive to the population and more conducive to generating scale agglomeration effects and increasing population agglomeration.

(4) For the strongly polycentric UAs, there is a weakening of the explanatory power of the five influencing factors of *Tpv*, *Gies*, *Wag*, *Edu*, and *Wel*. Meanwhile, the explanatory power of *Urb* on the spatial distribution of population agglomeration is always the strongest from 2000 to 2020, with the explanatory power being 0.470, 0.547, and 0.593, respectively, and passing the significance test at the 1% level. This type of UAs tends to have multiple central cities with closer inter-city ties, making it easier for the population to disperse to the various levels of cities within the UAs, which also allows for greater mobility and thus higher population agglomeration.

Table 6. Detection Results of Factors Influencing the Spatial Stratified Heterogeneity of the Population Patterns of the Four UAs (from 2000 to 2020).

Indicators	Weakly Polycentric UAs			Weakly Moncentric UAs			Strongly Moncentric UAs			Strongly Polycentric UAs		
	2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020
PerGDP	0.051	0.006	0.136 *	0.050	0.200	0.299	0.424 ***	0.494 ***	0.417 ***	0.167	0.182	0.179
Ind	0.022	0.019	0.054	0.239	0.351	0.302	0.048	0.229 **	0.133	0.208 *	0.267 **	0.293 **
Fai	0.010	0.018	0.016	0.050	0.578 ***	0.539 **	0.178 *	0.308 ***	0.336 ***	0.068	0.069	0.091
Tpv	0.223 ***	0.200 **	0.233 ***	0.230	0.270	0.301	0.129	0.305 ***	0.236 **	0.176	0.249 **	0.167
Tfv	0.045	0.029	0.060	0.306	0.242	0.476 **	0.138	0.287 ***	0.289 ***	0.026	0.068	0.215 *
Tpvmd	0.076	0.129 *	0.119	0.333 *	0.479 **	0.596 ***	0.249 **	0.219 **	0.269 **	0.228 **	0.195 *	0.470 ***
Ilei	0.102	0.199 **	0.213 ***	0.434	0.501 **	0.554 ***	0.199 *	0.313 ***	0.367 ***	0.105	0.099	0.352 ***
Gies	0.141 *	0.054	0.030	0.167	0.464 **	0.419 *	0.238 **	0.323 ***	0.345 ***	0.177	0.187 *	0.060
Exp	0.085	0.013	0.099	0.284	0.485 **	0.586 ***	0.316 ***	0.234 **	0.378 ***	0.247 **	0.171	0.290 **
Wag	0.012	0.011	0.083	0.313	0.010	0.178	0.308 ***	0.475 ***	0.446 ***	0.297 **	0.186 *	0.151
Edu	0.058	0.122 *	0.160 **	0.082	0.060	0.124	0.182 *	0.148	0.108	0.113	0.177	0.108
Wel	0.048	0.078	0.049	0.134	0.159	0.210	0.225 **	0.047	0.046	0.194 *	0.033	0.117
Iwt	0.062	0.052	0.094	0.140	0.255	0.123	0.087	0.152	0.127	0.012	0.069	0.066
Gcr	0.199 **	0.100	0.166 **	0.272	0.277	0.287	0.038	0.162	0.193 *	0.025	0.134	0.026
Urb	0.075	0.037	0.079	0.199	0.174	0.461 ***	0.346 ***	0.420 ***	0.518 ***	0.470 ***	0.547 ***	0.593 ***

Note: *, **, and *** represent significance level at 10%, 5%, and 1%, respectively.

4. Discussion

4.1. Comparative Study

In analyzing the population mobility and agglomeration characteristics of UAs, it has been found that the population mobility of the five major UAs with high levels of economic development in China shows a spatial pattern of both agglomeration and diffusion, while the trend of population agglomeration to the central cities remains unchanged [93]. Specifically, the spatial distribution of population in the YRD urban agglomerations shows a clear "central-edge" structure [48]. The trend of population agglomeration in the Changsha–Zhuzhou–Xiangtan urban agglomeration is obvious [50]. The Wuhan metropolitan area shows the characteristics of "strong central city-edge city" [49]. The population of the Beijing metropolitan area is gradually dispersed to the periphery, and the trend of polycentric spatial structure is strengthened [69]. In analyzing the population agglomeration patterns of 19 UAs in China from 2000 to 2020, this study finds strong similarities with existing studies; i.e., although most UAs show a trend of increasing population agglomeration, the unevenness of their population spatial distribution is gradually increasing, especially for the less developed UAs, because the population primacy degree is increasing as their central cities develop vigorously and gradually pull away from the population size of other classes of cities. The difference in this study is that some of the UAs with a higher degree of development show not only a centripetal concentration of population in the central city but also a diffusion of population from the central city to the outside. The increased mobility of the population in UAs refers not only to more frequent population movements within UAs but also to closer linkages between UAs and UAs, resulting in greater variation in the state and degree of mobility within UAs. Such changing characteristics further enrich the types of population agglomeration patterns in Chinese UAs, which need to be studied in depth.

In analyzing the classification and the evolution patterns of population agglomeration patterns in UAs, studies have been conducted both from data such as population census data, statistical data, or data from dynamic monitoring surveys of mobile populations [45,55] and from the Gini index, centrality index, and urban agglomeration development [54,56]. In this study, when population agglomeration degree and population primacy degree are used to classify the population agglomeration patterns of UAs, certain similarities with existing studies are found; i.e., strong polycentric UAs are mainly located in UAs with higher development and higher population mobility, while weak polycentric UAs are mainly located in UAs with lower development and lower population mobility. The difference is that, because of the large number of UAs in China, their different locations, and different degrees of economic development, their population agglomeration and flow dynamics also differ greatly, so the process of classifying the population agglomeration patterns of UAs needs to be more refined. Therefore, based on the four categories of urban agglomeration patterns, this study continues to classify eight subcategories according to the net inflow or outflow of population in the UAs as a whole, which can, to a certain extent, more accurately classify the types of urban agglomeration patterns in Chinese UAs. At the same time, this study also classifies urban agglomeration types by nighttime lighting data, which further supports the scientificity of this study's classification.

While analyzing the influencing factors of population agglomeration in UAs, more studies have been conducted from a certain factor, such as the degree of economic development, transportation convenience, public service supply, and air quality in terms of natural environment, economic development, and social conditions, which are not comprehensive enough in the analysis process [82,94]. In this study, on the other hand, 15 indicators are selected to explore the influencing factors of population agglomeration in UAs from the factors of both economic development and social conditions, and the spatially stratified heterogeneity characteristics of the influencing factors are analyzed by geographic detector model. Similar to existing studies, economic development factors and social conditions factors are important factors influencing population mobility and distribution. Cities with higher levels of economic development, more employment opportunities, higher labor compensation, and stronger public service supply capabilities are more attractive to the

population and have higher levels of population agglomeration. This study differs from other studies in that the population agglomeration degrees of cities in different urban agglomeration patterns have different influencing factors. For weakly polycentric UAs, the convenient transportation network helps the flow of various factors, and the total passenger volume has a stronger contribution to their population agglomeration, while, for UAs with stronger population agglomeration, the contribution of urbanization rate is more obvious.

4.2. Additional Analysis from Other Perspectives

In this study, different types of population agglomeration in Chinese UAs are classified into weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric based on the evolutionary law of population agglomeration, but the results of different types of UAs centers are difficult to be verified due to the strong spatial correlation between population agglomeration and economic agglomeration in urban agglomeration space. Therefore, in order to supplement the classification results of population agglomeration patterns in UAs, Suomi National Polar-orbiting Partnership/Visible Infrared Imaging Radiometer Suite NTL data of 2000, 2010, and 2020 are used to identify the economic agglomeration centers of UAs and to compare the similarities and differences between population agglomeration and economic agglomeration centers [31,70]. The results are shown in Figure 6. It can be found that only three UAs, BBG, GZH, and HBEY, evolve from monocentric UAs in 2000 to polycentric UAs in 2020, with multiple central regions forming within them. The other 16 types of UAs are the ones where only the area of the central area has been expanded, while the others remain unchanged. Overall, polycentric UAs are the main type, with the number of 10 in 2000 increasing to 13 in 2020. As for the six UAs of HBCC, WCFS, MSLN, SDP, MYZ, and CPL, they are identified by the NTL data to exist in multiple central regions, belonging to polycentric UAs, and the population agglomeration model of the UAs also identifies that its primary city has a small population gap with its secondary city, and there exist two or more large cities with populations that belong to polycentric UAs. The identification results of both are in perfect agreement. Overall, the economic agglomeration polycenter identified by NTL data is basically similar to the results of this study's classification, which supports the scientificity of this study's UAs type based on the population agglomeration model.

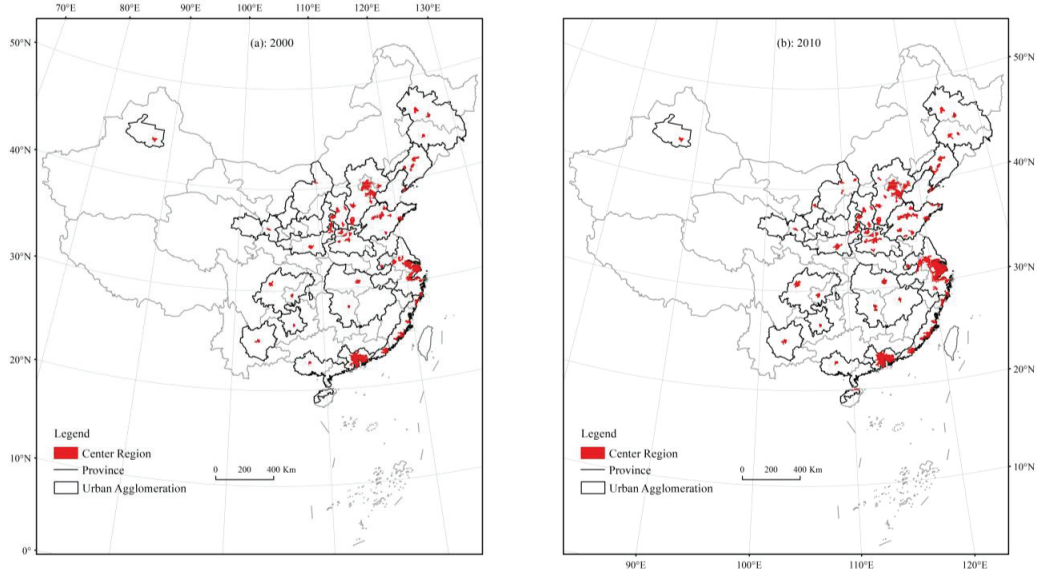


Figure 6. *Cont.*

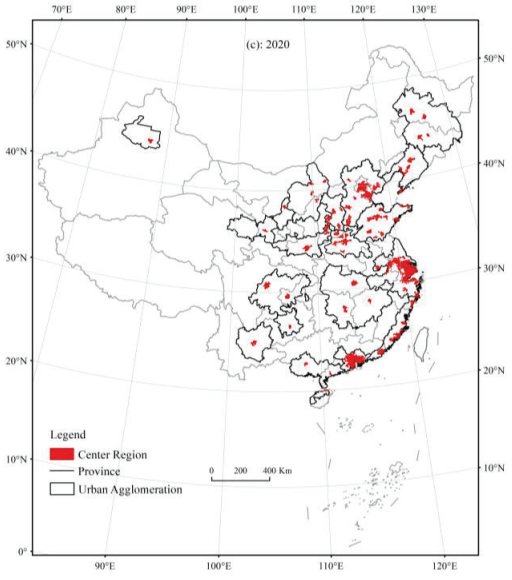


Figure 6. Range of UAs Centers Identified by NTL Data ((**a**): 2000; (**b**): 2010; (**c**): 2020).

4.3. Implications of the Study

In theory, by analyzing the population migration characteristics presented by 19 UAs, it is found that the population agglomeration patterns of Chinese UAs go through the evolution patterns of weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs. Meanwhile, this study finds that the evolution of population agglomeration patterns of UAs has distinctive stage and regional characteristics; that is, the population of the weakly polycentric UAs is characterized by "agglomeration in outflow", weakly monocentric UAs show "absolute concentration", while the strongly monocentric UAs show "relative concentration", and strongly polycentric UAs show a "relatively decentralized" characteristic. In conclusion, this study provides a more in-depth exploration of the characteristics of population mobility and agglomeration within UAs, enriching the theoretical and practical results of population migration and polycentric UAs research based on the existing studies [66].

In methods, by using population data, this study classifies the population agglomeration patterns into four major categories, namely weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs, by using two indices, namely population agglomeration degree and population primacy degree, which has not been carried out in previous studies. Meanwhile, there are obvious differences in the population agglomeration patterns of different UAs because of the large number of UAs in China, their different locations, and different degrees of economic development. Therefore, based on the four categories of urban agglomeration patterns, this study continues to classify eight subcategories according to the net inflow or outflow of population in the UAs as a whole, which can, to a certain extent, more accurately classify the types of urban agglomeration patterns in Chinese UAs. Such processes have not been carried out in previous studies.

In conclusion, the spatially stratified heterogeneous characteristics of the influencing factors of population agglomeration are obtained in this study using the geographic detector model. The study shows that economic development factors and social condition factors are important factors influencing population mobility and distribution, and that different urban agglomeration patterns have differential influencing factors on urban population agglomeration. For weakly polycentric UAs, their relatively low level of economic development results in limited attractiveness to the population, while a convenient trans-

portation network facilitates the free mobility of population factors and helps increase the population agglomeration degree. For weakly monocentric UAs, due to their relatively limited level of economic development, more job opportunities and more quality public services are important to attract population. For strongly monocentric UAs and strongly polycentric UAs, based on their higher level of economic development, the establishment of closer economic and social ties and the realization of a higher urbanization rate are more likely to exert a scale agglomeration effect, which in turn enhances the attractiveness of the population to increase the degree of population agglomeration.

4.4. Study Deficiencies and Prospects

This study analyzes the evolution characteristics and influencing factors of the population agglomeration patterns of UAs using three cross-sectional datasets from the fifth, sixth, and seventh censuses and statistical yearbook data, focusing on the population perspective to explore the population agglomeration patterns of UAs, with more emphasis on long time and dynamic analysis. In addition, although the UAs types in 2000, 2010, and 2020 are identified by NTL data and are compared with the population agglomeration patterns of UAs identified by demographic data, which, to a certain extent, supports the scientificity of demographic data classification, population migration is actually a real-time and dynamic process, which means the characteristics and patterns of population migration in China's UAs revealed in this study are partial to a certain extent, and subsequent refined analyses are needed to combine with big data on UAs migration and other data, and it is also necessary to explore the differential impacts of population migration in different types of UAs on the development of UAs. Further, considering the complexity of UAs in China, the population evolution characteristics of different UAs in the long term can be analyzed for a single or a few UAs. Meanwhile, the population mobility characteristics of different UAs in the short term can also be analyzed by using new data, such as location data, and then compare and analyze with the population mobility characteristics presented in the long term of UAs. We can also continue to explore the influencing factors of population agglomeration from different factors, such as natural environment, economic development, social conditions, etc., which can provide a reference for the formulation of population policies in different UAs.

5. Conclusions

Using the data of China's fifth, sixth, and seventh population censuses, statistical yearbooks, NTL data, and other data, this study discusses and analyzes the characteristics of population migration, evolution rules, and influencing factors of population agglomeration patterns in UAs in China by combining with the methods of geographic detector model, population agglomeration degree, population primacy degree, and net migration rate. The main conclusions obtained are as follows:

(1) UAs are the main areas with high population agglomeration in China. The more developed UAs are, the more attractive they are to the population, and the higher their population agglomeration degree and net migration rates would be. The attraction of UAs to population leads to an increase in the unevenness of population distribution in China, as well as the unevenness degree of population distribution within UAs with different levels of development in China.

(2) The population agglomeration patterns of Chinese UAs can be divided into four major categories, namely weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs, and will undergo the evolution pattern of weakly polycentric, weakly monocentric, strongly monocentric, and strongly polycentric UAs. From 2000 to 2020, China's UAs are in a low-level stage dominated by weakly polycentric UAs. Additionally, it is also found that the types of UAs obtained by NTL data are generally consistent with the population agglomeration patterns of UAs derived from population data in this study.

(3) From the perspective of factors influencing population agglomeration in UAs, the factors influencing population agglomeration patterns in different UAs are quite different. The explanatory power of total passenger volume to weakly polycentric UAs is always the strongest, the explanatory power of industrial location entropy index, scale of fiscal expenditure, and total passenger volume of municipal district is relatively strong for weakly monocentric UAs, while the explanatory power of per capita GDP and urbanization rate is relatively strong for strongly monocentric UAs, with the urbanization rate always being the strongest explanatory power for strongly polycentric UAs.

This study analyzes the evolutionary characteristics and influencing factors of population agglomeration patterns of UAs in China from the scale of UAs, and the findings provide a basis for formulating UAs development plans in China. In the process of analyzing the influencing factors of population agglomeration patterns, the study finds that the contribution of urbanization rate is more obvious for UAs with stronger population agglomeration, and its contribution has been increasing.

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References

1. United Nations Department of Economic and Social Affairs. *World Urbanization Prospects: The 2018 Revision*; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2018.
2. Kundu, D.; Pandey, A.K. World urbanisation: Trends and patterns. In *Developing National Urban Policies: Ways forward to Green and Smart Cities*; Kundu, D., Sietchiping, R., Kinyanjui, M., Eds.; Springer: Singapore, 2020; pp. 13–49.
3. Chen, Y.; Liu, Z.; Zhou, B. Population-environment dynamics across world's top 100 urban agglomerations: With implications for transitioning toward global urban sustainability. *J. Environ. Manag.* **2022**, *319*, 115630. [CrossRef]
4. Clark, B. Ebenezer Howard and The Marriage of Town and Country: An introduction to Howard's Garden Cities of Tomorrow (selections). *Organ. Environ.* **2003**, *16*, 87–97. [CrossRef]
5. Gottmann, J. Megalopolis or the urbanization of the northeastern seaboard. *Econ. Geogr.* **1957**, *33*, 189–200. [CrossRef]
6. McGee, T.G. Managing the rural–urban transformation in East Asia in the 21st century. *Sustain. Sci.* **2008**, *3*, 155–167. [CrossRef]
7. Scott, A.J. Globalization and the Rise of City-regions. *Eur. Plan. Stud.* **2001**, *9*, 813–826. [CrossRef]
8. Lang, R.; Knox, P.K. The New Metropolis: Rethinking Megalopolis. *Reg. Stud.* **2009**, *43*, 789–802. [CrossRef]
9. Chan, R.C.K.; Yao, S. Urbanization and sustainable metropolitan development in China: Patterns, problems and prospects. *GeoJournal* **1999**, *49*, 269–277. [CrossRef]
10. Zhou, Y. Definition of urban place and statistical standards of urban population in China: Problem and solution. *Asian Geogr.* **1988**, *7*, 12–18.
11. Xu, X.; Lin, X.; Zhou, C. A review of the research process of foreign metropolitan areas and its enlightenment. *Urban Plan. Forum* **2007**, *168*, 9–14.
12. Fang, C.; Mao, Q.; Ni, P. Discussion on the scientific selection and development of China's urban agglomerations. *Acta Geogr. Sin.* **2015**, *70*, 515–527.
13. Zhang, G.; Huang, W.; Zhou, C.; Cao, Y. Spatio-temporal characteristics of demographic distribution in China from the perspective of urban agglomeration. *Acta Geogr. Sin.* **2018**, *73*, 1513–1525.
14. Ruyssen, I.; Rayp, G. Determinants of Intraregional Migration in Sub-Saharan Africa 1980–2000. *J. Dev. Stud.* **2014**, *50*, 426–443. [CrossRef]
15. Liang, Z.; Li, Z.; Ma, Z. Changing Patterns of the Floating Population in China, 2000–2010. *Popul. Dev. Rev.* **2014**, *40*, 695–716. [CrossRef]

16. Qi, W.; Abel, G.J.; Liu, S. Geographic transformation of China's internal population migration from 1995 to 2015: Insights from the migration centerline. *Appl. Geogr.* **2021**, *135*, 102564. [CrossRef]
17. Jinghu Pan, J.L. Research on spatial pattern of population mobility among cities: A case study of "Tencent Migration" big data in "National Day–Mid-Autumn Festival" vacation. *Geogr. Res.* **2019**, *38*, 1678–1693.
18. Zhu, Y.; Chen, W. The settlement intention of China's floating population in the cities: Recent changes and multifaceted individual-level determinants. *Popul. Space Place* **2010**, *16*, 253–267. [CrossRef]
19. Bosker, M.; Buringh, E. City seeds: Geography and the origins of the European city system. *J. Urban Econ.* **2017**, *98*, 139–157. [CrossRef]
20. Gao, X.; Xu, Z.; Niu, F.; Long, Y. An evaluation of China's urban agglomeration development from the spatial perspective. *Spat. Stat.* **2017**, *21*, 475–491. [CrossRef]
21. Chen, L. Theoretical basis and empirical studies of agglomeration economy influencing urban economic growth: Literature review and prospect. *Prog. Geogr.* **2022**, *41*, 1325–1337. [CrossRef]
22. Zhao, M.; Derudder, B.; Huang, J. Examining the transition processes in the Pearl River Delta polycentric mega-city region through the lens of corporate networks. *Cities* **2017**, *60*, 147–155. [CrossRef]
23. Liu, X.; Yan, X.; Wang, W.; Titheridge, H.; Wang, R.; Liu, Y. Characterizing the polycentric spatial structure of Beijing Metropolitan Region using carpooling big data. *Cities* **2021**, *109*, 103040. [CrossRef]
24. Deng, Y.; Liu, J.; Liu, Y.; Luo, A. Detecting Urban Polycentric Structure from POI Data. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 283. [CrossRef]
25. Huang, Y.; Liao, R. Polycentric or monocentric, which kind of spatial structure is better for promoting the green economy? Evidence from Chinese urban agglomerations. *Environ. Sci. Pollut. Res.* **2021**, *28*, 57706–57722. [CrossRef]
26. Wang, X.; Li, X.; Zhang, S. Has the polycentric spatial structure promoted high-quality urban development. *China Popul. Resour. Environ.* **2022**, *32*, 57–67.
27. Zhu, Z.; Zheng, B.; He, Q. Study on Evolution of Spatial Structure of Pearl River Delta Urban Agglomeration and its Effects. *Econ. Geogr.* **2011**, *31*, 404–408.
28. Wang, C.; Liu, X. The Influence of Polycentric Spatial Structure of Urban Agglomeration on Rural Revitalization: Based on 19 Urban Agglomerations in China. *Econ. Geogr.* **2023**, *43*, 55–63.
29. Sun, T. Evolution of Agglomeration and Its Spatial Structure with Economic Growth in Three Major Metropolitan Regions of China. *Econ. Geogr.* **2016**, *36*, 63–70.
30. Li, W.; Sun, B.; Zhang, T.; Zhang, Z. Polycentric spatial structure and its economic performance: Evidence from meta-analysis. *Reg. Stud.* **2022**, *56*, 1888–1902. [CrossRef]
31. Li, Y.; Derudder, B. Dynamics in the polycentric development of Chinese cities, 2001–2016. *Urban Geogr.* **2020**, *43*, 272–292. [CrossRef]
32. Liu, X.; Wang, M. How polycentric is urban China and why? A case study of 318 cities. *Landsc. Urban Plan.* **2016**, *151*, 10–20. [CrossRef]
33. Yu, H.; Yang, J.; Li, T.; Jin, Y.; Sun, D. Morphological and functional polycentric structure assessment of megacity: An integrated approach with spatial distribution and interaction. *Sustain. Cities Soc.* **2022**, *80*, 103800. [CrossRef]
34. Brezzi, M.; Veneri, P. Assessing Polycentric Urban Systems in the OECD: Country, Regional and Metropolitan Perspectives. *Eur. Plan. Stud.* **2014**, *23*, 1128–1145. [CrossRef]
35. Phelps, N.A. Clusters, Dispersion and the Spaces in Between: For an Economic Geography of the Banal. *Urban Stud.* **2016**, *41*, 971–989. [CrossRef]
36. Combes, P.-P.; Duranton, G.; Gobillon, L. Spatial wage disparities: Sorting matters! *J. Urban Econ.* **2008**, *63*, 723–742. [CrossRef]
37. Connolly, C.; Keil, R.; Ali, S.H. Extended urbanisation and the spatialities of infectious disease: Demographic change, infrastructure and governance. *Urban Stud.* **2020**, *58*, 245–263. [CrossRef]
38. Cervero, R. Efficient Urbanisation: Economic Performance and the Shape of the Metropolis. *Urban Stud.* **2016**, *38*, 1651–1671. [CrossRef]
39. Zhu, D.; Wang, Y.; Peng, S.; Zhang, F. Influence Mechanism of Polycentric Spatial Structure on Urban Land Use Efficiency: A Moderated Mediation Model. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16478. [CrossRef]
40. Han, S.; Sun, B.; Zhang, T. Mono- and polycentric urban spatial structure and PM2.5 concentrations: Regarding the dependence on population density. *Habitat Int.* **2020**, *104*, 102257. [CrossRef]
41. Han, S.; Miao, C. Does a Polycentric Spatial Structure Help to Reduce Industry Emissions? *Int. J. Environ. Res. Public Health* **2022**, *19*, 8167. [CrossRef]
42. Yang, J.; French, S.; Holt, J.; Zhang, X. Measuring the Structure of U.S. Metropolitan Areas, 1970–2000. *J. Am. Plan. Assoc.* **2012**, *78*, 197–209. [CrossRef]
43. Chen, H.; Luo, H.; Song, J. Population distribution and industrial evolution of the Tokyo Metropolitan Area. *Prog. Geogr.* **2020**, *39*, 1498–1511. [CrossRef]
44. Yi, D.; Shi, Y. Population Distribution, Growth Pole and Incubation of World-class Megalopolis: A Comparison between Northeastern Megalopolis in the United States and Beijing-Tianjin-Hebei Megalopolis in China. *Popul. Res.* **2016**, *40*, 87–98.
45. Hajrasouliha, A.H.; Hamidi, S. The typology of the American metropolis: Monocentricity, polycentricity, or generalized dispersion? *Urban Geogr.* **2016**, *38*, 420–444. [CrossRef]

46. Bailey, N.; Turok, I. Central Scotland as a Polycentric Urban Region: Useful Planning Concept or Chimera? *Urban Stud.* **2016**, *38*, 697–715. [CrossRef]
47. Yan, D.; Sun, W.; Wang, Y.; Xu, S. Change in distribution and growth shifts of population in the Yangtze River Delta and influencing factors. *Prog. Geogr.* **2020**, *39*, 2068–2082. [CrossRef]
48. Xue, F.; Li, M.; Dang, A. Centrality and Symmetry of People Flow Network Structure of the Yangtze River Delta Urban Agglomeration at Multi-Spatial Scales. *Econ. Geogr.* **2020**, *40*, 49–58.
49. Zheng, B.; Zhong, Y. Study on Spatial Structure of Population Migration Network of Urban Agglomeration in the Middle Yangtze River Based on Complex Network. *Econ. Geogr.* **2020**, *40*, 118–128.
50. He, Y.; Zhou, G.; Tang, C.; Fan, S.; Guo, X. The spatial organization pattern of urban-rural integration in urban agglomerations in China: An agglomeration-diffusion analysis of the population and firms. *Habitat Int.* **2019**, *87*, 54–65. [CrossRef]
51. Wang, Z.; Yang, S.; Gong, F.; Liu, S. Identification of Urban Agglomerations Deformation Structure Based on Urban-flow Space: A Case Study of the Yangtze River Delta Urban Agglomeration. *Sci. Geogr. Sin.* **2017**, *37*, 1337–1344.
52. Shi, Y.; Zhu, Y.; Feng, D.; Wang, F.; Xiong, W. Polycentric Network Development Patterns of Zhongyuan Urban Agglomeration. *Sci. Geogr. Sin.* **2012**, *32*, 1431–1438.
53. Ye, Q.; Zhang, L.; Peng, P.; Huang, J. The Network Characteristics of Urban Agglomerations in the Middle Reaches of the Yangtze River Based on Baidu Migration Data. *Econ. Geogr.* **2017**, *37*, 53–59.
54. Song, J.; Fang, C.; Song, D. Spatial Structure Stability of Urban Agglomerations in China. *Acta Geogr. Sin.* **2006**, *61*, 1311–1325.
55. Sun, B.; Hua, J.; Li, W.; Zhang, T. Spatial structure change and influencing factors of city clusters in China: From monocentric to polycentric based on population distribution. *Prog. Geogr.* **2017**, *36*, 1294–1303.
56. Li, J.; Zhang, W.; Sun, T.; Zhang, A. Characteristics of clustering and economic performance of urban agglomerations in China. *Acta Geogr. Sin.* **2014**, *69*, 474–484.
57. Liu, X.; Derudder, B.; Wu, K. Measuring polycentric urban development in China: An intercity transportation network perspective. *Reg. Stud.* **2016**, *50*, 1302–1315. [CrossRef]
58. Lan, F.; Da, H.; Wen, H.; Wang, Y. Spatial Structure Evolution of Urban Agglomerations and Its Driving Factors in Mainland China: From the Monocentric to the Polycentric Dimension. *Sustainability* **2019**, *11*, 610. [CrossRef]
59. Borderon, M.; Sakdapolrak, P.; Muttarak, R.; Kebede, E.; Pagogna, R.; Sporer, E. Migration influenced by environmental change in Africa: A systematic review of empirical evidence. *Demogr. Res.* **2019**, *41*, 491–544. [CrossRef]
60. Reuveny, R.; Moore, W.H. Does Environmental Degradation Influence Migration_Emigration to Developed Countries in the Late 1980s and 1990s. *Soc. Sci. Q.* **2009**, *90*, 461–479. [CrossRef]
61. Hoffmann, R.; Dimitrova, A.; Muttarak, R.; Crespo Cuaresma, J.; Peisker, J. A meta-analysis of country-level studies on environmental change and migration. *Nat. Clim. Chang.* **2020**, *10*, 904–912. [CrossRef]
62. Alperovich, G. Economic development and population concentration. *Econ. Dev. Cult. Chang.* **1992**, *41*, 63–74. [CrossRef]
63. Liu, Y.; Shen, J. Spatial patterns and determinants of skilled internal migration in China, 2000–2005. *Pap. Reg. Sci.* **2014**, *93*, 749–771. [CrossRef]
64. Ye, C.; Zhu, J.; Li, S.; Yang, S.; Chen, M. Assessment and analysis of regional economic collaborative development within an urban agglomeration: Yangtze River Delta as a case study. *Habitat Int.* **2019**, *83*, 20–29. [CrossRef]
65. Zhang, P.; Zhao, Y.; Zhu, X.; Cai, Z.; Xu, J.; Shi, S. Spatial structure of urban agglomeration under the impact of high-speed railway construction: Based on the social network analysis. *Sustain. Cities Soc.* **2020**, *62*, 102404. [CrossRef]
66. Zhou, C.; Li, M.; Zhang, G.; Chen, J.; Zhang, R.; Cao, Y. Spatiotemporal characteristics and determinants of internal migrant population distribution in China from the perspective of urban agglomerations. *PLoS ONE* **2021**, *16*, e0246960. [CrossRef]
67. Wang, J.; Liu, B.; Li, Y. Spatial-temporal characteristics and influencing factors of population distribution and floating changes in Beijing-Tianjin-Hebei region. *Geogr. Res.* **2018**, *37*, 1802–1817.
68. Chen, M.; Guo, S.; Lu, D. Characteristics and spatial patterns of floating population in the Beijing-Tianjin-Hebei urban agglomeration under the background of new urbanization. *Prog. Geogr.* **2018**, *37*, 363–372.
69. Sun, T.; Han, Z.; Wang, L.; Li, G. Suburbanization and subcentering of population in Beijing metropolitan area: A nonparametric analysis. *Chin. Geogr. Sci.* **2012**, *22*, 472–482. [CrossRef]
70. He, X.; Cao, Y.; Zhou, C. Evaluation of Polycentric Spatial Structure in the Urban Agglomeration of the Pearl River Delta (PRD) Based on Multi-Source Big Data Fusion. *Remote Sens.* **2021**, *13*, 3639. [CrossRef]
71. Zeng, C.; Song, Y.; Cai, D.; Hu, P.; Cui, H.; Yang, J.; Zhang, H. Exploration on the spatial spillover effect of infrastructure network on urbanization: A case study in Wuhan urban agglomeration. *Sustain. Cities Soc.* **2019**, *47*, 101476. [CrossRef]
72. Fang, C.; Bao, C.; Ma, H. *China Urban Agglomeration Development Report in 2016*; Science Press: Beijing, China, 2017.
73. National Bureau of Statistics. *China City Statistical Yearbook 2021*; China Statistics Press: Beijing, China, 2020.
74. Office of the Leading Group of the State Council for the Fifth National Population Census. *Tabulation on 2000 China Population Census by County*; China Statistics Press: Beijing, China, 2000.
75. Office of the Leading Group of the State Council for the Seventh National Population Census. *Tabulation on 2020 China Population Census by County*; China Statistics Press: Beijing, China, 2020.
76. He, C.; Chen, T.; Mao, X.; Zhou, Y. Economic transition, urbanization and population redistribution in China. *Habitat Int.* **2016**, *51*, 39–47. [CrossRef]
77. Hunt, G.L. Equilibrium and disequilibrium in migration modelling. *Reg. Stud.* **1993**, *27*, 341–349. [CrossRef]

78. Cao, Z.; Zheng, X.; Liu, Y.; Li, Y.; Chen, Y. Exploring the changing patterns of China's migration and its determinants using census data of 2000 and 2010. *Habitat Int.* **2018**, *82*, 72–82. [CrossRef]
79. Shen, S.; Shen, G. Analysis on the Spatial Structure of Inter-provincial Migrant in China. *Popul. J.* **2020**, *42*, 103–112.
80. Fu, Y.; Gabriel, S.A. Labor migration, human capital agglomeration and regional development in China. *Reg. Sci. Urban Econ.* **2012**, *42*, 473–484. [CrossRef]
81. Wang, Z.; Xu, J.; Zhu, C.; Qi, Y.; Xu, L. The County Accessibility Divisions in China and Its Correlation with Population Distribution. *Acta Geogr. Sin.* **2010**, *65*, 416–426.
82. Chen, Y.; Mei, L. Quantitative Analysis of Population Distribution and Influencing Factors of Resource-based Cities in Northeast China. *Sci. Geogr. Sin.* **2018**, *38*, 402–409.
83. Bereitschaft, B.; Cammack, R. Neighborhood diversity and the creative class in Chicago. *Appl. Geogr.* **2015**, *63*, 166–183. [CrossRef]
84. Cui, C.; Wang, Z.; He, P.; Yuan, S.; Niu, B.; Kang, P.; Kang, C. Escaping from pollution: The effect of air quality on inter-city population mobility in China. *Environ. Res. Lett.* **2019**, *14*, 124025. [CrossRef]
85. Cao, G.; Liu, J.; Liu, T. Examining the role of air quality in shaping the landscape of China's internal migration: Phase characteristics, push and pull effects. *Geogr. Res.* **2021**, *40*, 199–212.
86. Buch, T.; Hamann, S.; Niebuhr, A.; Rossen, A. What Makes Cities Attractive? The Determinants of Urban Labour Migration in Germany. *Urban Stud.* **2014**, *51*, 1960–1978. [CrossRef]
87. Liu, S.; Deng, Y.; Hu, Z. Research on Classification Methods and Spatial Patterns of the Regional Types of China's Floating Population. *Acta Geogr. Sin.* **2010**, *65*, 1187–1197.
88. Liu, R.; Feng, Z.; You, Z. Research on the Spatial Pattern and Formation Mechanisms of Population Agglomeration and Shrinking in China. *China Popul. Resour. Environ.* **2010**, *20*, 89–94.
89. Jefferson, M. The Law of the Primate City. *Geogr. Rev.* **1939**, *29*, 226–232. [CrossRef]
90. Meijers, E.J.; Burger, M.J. Spatial Structure and Productivity in US Metropolitan Areas. *Environ. Plan. A Econ. Space* **2010**, *42*, 1383–1402. [CrossRef]
91. Wang, J.; Xu, C. Geodetector: Principle and prospective. *Acta Geogr. Sin.* **2017**, *72*, 116–134.
92. Li, H.; Zhang, M.; Wang, R. The effects of regional geographical factors on children's respiratory diseases in Jingyuan, Ningxia. *Geogr. Res.* **2019**, *38*, 2889–2898.
93. Cao, G.; Chen, S.; Liu, T. Changing spatial patterns of internal migration to five major urban agglomerations in China. *Acta Geogr. Sin.* **2021**, *76*, 1334–1349.
94. Guan, X.; Wei, H.; Lu, S.; Su, H. Mismatch distribution of population and industry in China: Pattern, problems and driving factors. *Appl. Geogr.* **2018**, *97*, 61–74. [CrossRef]

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Maturity Analysis of Stock Exchanges in Africa: Prepandemic Sustainability Perspective

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Abstract: This paper focuses on the economic dimension of sustainability by examining the stock exchange interface of financial markets, the influence of capital market stakeholders, and the instruments that contribute to a supportive fiscal framework. Only mature stock exchanges are present in sustainability indices; hence, comparative assessment of stock exchanges is limited and contributes to the complexity of conducting such a study. Utilizing multivariate analysis, this study investigates the potential for African stock exchanges to support sustainability. An empirical study was conducted on a selected sample of 15 African stock exchanges at the end of 2020 using collected 5-year interval data from Q1 of 2021. A total of 22 variables were selected based on their legitimacy to support sustainability. Using exploratory factor analysis, two key sustainability drivers of differentiation and classified exchanges were identified, i.e., hard and soft. K-means classification method verified the results and found that of the four identified homogeneous groups, one—the Johannesburg Stock Exchange, Nigerian Stock Exchange, and the Egyptian Exchange—emerged on top. Two smaller groups had the potential to be strengthened, and the majority group lagged behind. The research demonstrated the importance of identifying key sustainability drivers and examined the materiality of the drivers within an African context.

Keywords: sustainable development; explanatory factor analysis; k-means; United Nations Sustainable Development Goals

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1. Introduction

In the last few decades of the twentieth century, a shift from development in the economic sense to the concept of sustainability became increasingly common. The traditional model, i.e., contributing to the development and improvement of the quality of life of societies, was not considered beneficial for all to the same extent [1,2]. The negative effects were intensified mainly in the form of natural environmental degradation [1,3]. A new approach based on the idea of sustainable development was perceived as a solution to contemporary problems and challenges—emphasizing the need for a broader perspective within a triple bottom line approach [4–6], i.e., environmental, social, and economic dimensions. Sustainable development requires the involvement of many actors, including state institutions, multinational corporations, and enterprises [7,8], non-governmental organizations, and the community at large [9]. A key economic function of this involvement is capital markets, i.e., by supporting sustainable capital allocated by responsible investments and sustainability-oriented financing [10–12]. Research consideration focuses on the relevant architecture of stock exchanges in the context of responsible investing, as stock exchanges can achieve spectacular outcomes in terms of the United Nations Sustainable Development Goals (SDGs) [12,13]. To date, an emphasis on institutional quality has downplayed the concept of sustainability by focusing on key determinants of economic development [14].

Stock exchanges fulfill their basic function and prove their maturity by attracting foreign capital and long-term investments, as well as a developed institutional framework that provides trustworthiness [15]. Bodie et al. [16] point out the importance of market transparency for informed decisions. Alley [17] indicates that there is still no consensus on the impact of foreign capital flows in terms of economic wealth, even though it has been well deliberated throughout the literature. Doubts concerning the role of foreign equity arise from the fact that capital might be volatile or speculative [17,18]. Strong requirements by foreign investors to use transparent accounting standards result in a lower risk of illegal activities, e.g., zero tolerance for corruption [19]. Similarly, long-term investors, such as pension funds, are more likely to focus on sustainable aspects, especially as they are subject to strict requirements, e.g., those related to anti-money laundering. The development issues mentioned are relevant to the development problems of Africa's financial markets.

Due to the potential of the market, available natural resources, the pace of development, and the gap in integrating into the world economy, Africa is an extremely important and emerging research area. Although, in recent years, the continent has been one of the fastest developing regions [20], it still remains a place of many challenges, including urban demographic growth, poverty, climate change, access to medical and educational services, and infrastructure underdevelopment [21]. Many African economies are heavily dependent upon natural resources—even those that are nonrenewable and quickly depleting [22,23]. It is crucial that all the actions undertaken to solve these problems must go hand in hand with sustainable production and consumption patterns as well as deep social change. This paper aims to utilize a multivariate analysis to examine the potential of stock exchanges in Africa that support sustainable development by identifying the key sustainability drivers and probing the materiality of these drivers within selected stock exchanges by classifying them in terms of the environmental—social—governance (ESG) approach. Multidimensional comparative analysis techniques are used to comparatively determine the sustainability of the selected stock exchanges. The structure of the paper is as follows: brief literature review on stock exchanges and sustainability in Africa; empirical framework containing a selection of stock exchanges, description of the set of variables utilized, and estimation of measures; explanatory factors analysis (EFA) and k-means verification—results and discussion; and concluding recommendations and limitations of the study.

2. Literature Review

2.1. Impact of Stock Exchanges in Africa

Among the few studies on stock exchanges in Africa [24], general issues include underdevelopment [24–28] or weaknesses of individual exchanges caused by, among other factors, sustainability deficiencies in the institutional framework (e.g., the Nigerian Stock Exchange (NSE) [15]) have been predominant (Figure 1—left). Andrianaivo and Yartey [29] underline the general determinants of financial market development, those being stock market liquidity, domestic savings as a main source of stock investments, development of the banking sector, and political risk. Odera [28] draws attention to the fact that the low liquidity of exchanges enables support for the local market via trading systems or brokers since the business volume is low. Other weaknesses of African capital markets include low levels of investor protection and innovation, underdeveloped trading systems or high initial public offering barriers for smaller companies, weak regulatory framework, and low foreign capital [27,30]. At present, only some stock exchanges in Africa are developed—varying deeply due to historical conditions, regulations, and performance. Three different groups of stock exchanges can be distinguished: (1) those founded between the turn of the nineteenth century, those established in the 1990s, and recently opened small exchanges in the last two decades. As a standout exchange and in comparison with other stock exchanges in Africa, the Johannesburg Stock Exchange (JSE) clearly dominates the continent, since it is also the nineteenth largest exchange in the world [30].

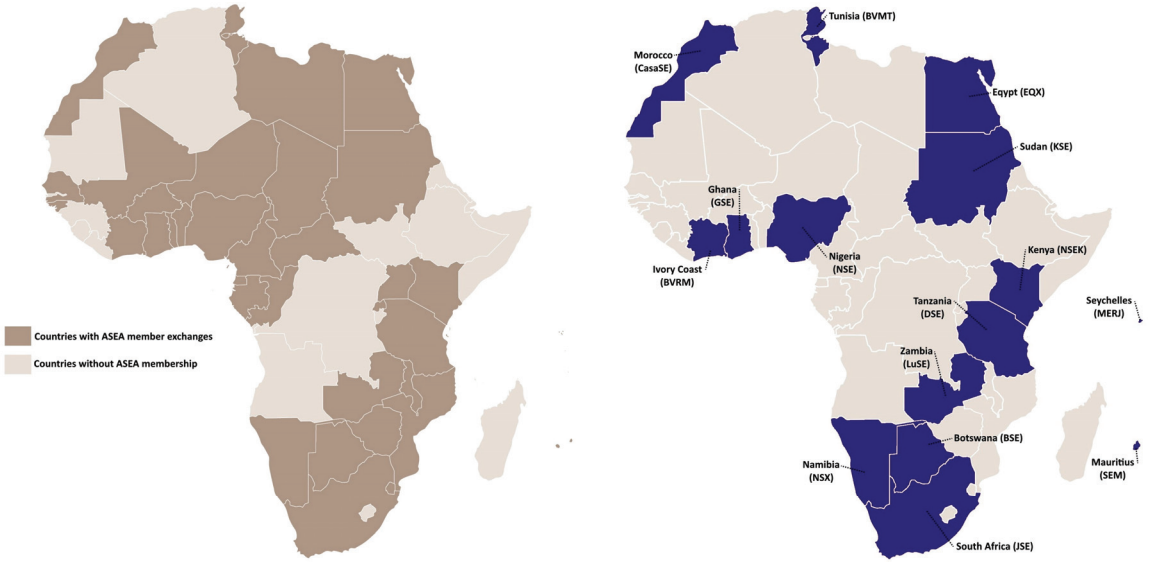


Figure 1. (**left**) African Securities Exchanges Association (ASEA) member exchanges, adapted from Raubenheimer [30], and (**right**) selected countries in the study.

Klagge and Zademach [25] document that the increase in stock exchanges and investment funds operating in Africa does not entail sufficient investment for the continent. This lack of financing, unfortunately, occurs even if the arbitrage theory suggests that the temptation of higher returns in developing countries should attract investors from developed ones. In terms of the low attractiveness for foreign flows of adequate size for domestic companies, Alley [17] states the poverty cycle can be overcome if the financing gap, i.e., a result of low levels of savings and investment, is bridged by foreign direct investment (FDI). However, Raubenheimer [30] noted foreign capital restrictions in some countries, such as Zimbabwe, which restricts foreign investors to no more than 49% equity in any enterprise, and Mauritius, which has foreign ownership restrictions on sugar companies. Any doubtful influence of the financial sector on the economic stability and development model [31,32] is dispelled by prevailing research on the key role of financial markets in economic growth [11,33–38], for example, something which has been diversely developed throughout the African continent. Assefa and Mollick [39] cite research on the importance of African stock markets but with no impact assessment. More consistent conclusions have been derived from research on institutions as a fundamental development factor. Using the example of the sub-Saharan African region, Bonuedi et al. [40] depict the positive and statistically significant association between institutions and real income per capita and, hence, the importance of well-performing and strong institutions for economic growth.

2.2. Sustainability of Stock Markets

According to the United Nations Conference on Trade and Development [12,41], stock exchanges, as intermediary platforms, may contribute to sustainability via two mechanisms: (1) guiding, supporting, and promoting good corporate practices within business and (2) providing a platform for sustainable finance through the mobilization of financial resources using sustainable products and channeling them into sustainability-oriented investments. Converging conclusions were recalled by Busch et al. [42] in terms of the capital market influence on enterprise sustainability. Moreover, financial and investor advocacy influence is noted as key to fostering and facilitating better sustainable business practices. Zhan and Santos-Paulino [13] also consider stock exchanges as providers of a platform for sustainable finance and guidance for corporate governance. A broad approach

to describing various tools and activities for sustainable development can be found in the Sustainable Stock Exchanges Initiative (SSEI) [43], the World Federation of Exchanges (WFE) [44], and ASEA [45]. These publications are also underlined by Kalinowski [46], who used some of the SSEI factors, such as indices or supporting market participants, by offering guides on responsible investing and sustainability disclosure to assess the involvement of stock exchanges in sustainable development. In a guideline for stock exchanges in terms of sustainable practices, additional elements such as stakeholder engagement, incorporating ESG issues into vision and mission statements, reflecting sustainability in governance and risk management, and communicating sustainable commitment [47] can be found. In the literature on sustainable development, studies referring to selected tools are bountiful, including sustainability metrics for evaluation of ESG performance (i.e., ratings, indices, and rankings) as well as sustainability-themed products, e.g., bonds. Various sustainability scoring methods are discussed in the literature, though they are mostly dealt with at the country [48] or enterprise level. Examples of metrics include Vigeo-EIRIS, KLD, MSCI, Morningstar, and Sustainanalytics; however, only several of the best-performing world stock exchanges are present in sustainability indices, such as Swiss Re's Sustainability Report [49], and even if present, they are assessed only as enterprises of the financial sector. More often adopted, one can observe stock exchange ESG indices implemented for sustainability performance as an important element of socially responsible investment (e.g., Marcinkowska [50]). The most recognizable indices include KLD's Domini 400, Dow Jones Sustainability Indexes, and the FTSE4Good Index Series [51].

The existence of sustainability indices organizes the market by identifying entities that meet sustainability-oriented requirements and enables investors to combine financial goals with environmental and social objectives. Such indices also enable the assessment of organizations (e.g., Sikacz [52] and Slager and Chapple [53]); thus, ESG indices can contribute to socially responsible investment [54]. They are also important for enterprises listed on stock exchanges as they encourage continuous improvement of sustainability performance [52–54]. Some authors notice the relationship between the ESG stock indices and risk. Yilmaz et al. [55] note that indexed enterprises may be a lower-risk stock, while others point out the lower corporate financing costs caused by lower risk [56]. ESG indices and the companies listed there appear in publications on the impact of the implementation of sustainable business principles in terms of their results (e.g., Lean and Pizzutilo [57] and Nitani et al. [58]). Researchers are also interested in ESG criteria and their improvement (e.g., Ho [59]).

When analyzing the stock exchange as an intermediary financial platform, dedicated sustainability bonds are also considered [60]. A number of publications mention numerous categories of such bonds, enabling the financing of activities in accordance with sustainable development. In this case, such terminology as ESG, sustainability, the SDGs, transition, development impact, social impact, green, climate, blue, and even COVID-19 response bonds can be found [61–64]. One of the most popular is green bonds used by economic entities for financing sustainable investments and pro-ecological projects (e.g., Maltais and Nykvist [10], Park [65], and Russo et al. [66]). Green bond listings were an integral part of SSEI [67] because stock exchanges are important actors in green bond market development since they can provide market liquidity and regulated, transparent trading platforms [68]. In 2017, according to SSEI [69], only around 0.2% of total bond issuance worldwide was made up of labeled green bonds. Although the sustainable bond market is growing, it is still hardly applicable to the least developed countries, especially in terms of Africa, when juxtaposed with other developing regions [70,71]. As such, about 90% of such funds and bonds are concentrated in developed countries [13]. Similarly, African markets are severely affected by climate change, making sustainable financing awareness strongly required continent-wide [70].

2.3. Concept from the Gaps in the Literature

Based on the literature, the following two hypotheses (H) and five research questions (RQ) provide for the research gaps.

2.3.1. Hypotheses

Hypothesis 1 (H1). *Stock exchanges motivate, i.e., trigger, companies to be more sustainable and transparent.*

Hypothesis 2 (H2). *The level of preparedness for the sustainability approach of African stock exchanges to support local economies (i.e., entities operating on African markets) is high.*

2.3.2. Research Questions

RQ1. Are African stock exchanges ready for foreign capital? This relates to the potential of African markets' readiness for international capital requirements.
RQ2. What is the role of African stock exchanges in sustainable development?
RQ3. Do active and matured stock exchanges engage more strongly in sustainable development given foreign investors, conglomerates, and companies in international supply chains? This relates to whether they are obliged to act sustainability and whether regulatory requirements exist and are enforced.
RQ4. What makes African markets attractive, and how could they fulfill and perform the functions of the financial market, according to Bodie et al. [16]?
RQ5. Are African markets attractive from the perspective of global investors under the growing amount of assets they manage?

3. Materials and Methods

This research was carried out in five stages. First, it was based on a deep review of the literature and pieced together using a set of variables (i.e., two quantitative and 20 qualitative) to describe exchanges. The quantitative criteria were ultimately used to select the research sample of exchanges and then to differentiate the performance of stock exchanges in the study process. The authors assumed that well-performing stock exchanges should create a greater potential to support sustainable development. Second, the initial set of 22 variables was reduced to six measures. Third, EFA with the varimax rotation method was applied to identify two latent factors of differentiation of exchanges. Fourth, using the latent factors as key drivers, stock exchanges were classified into four groups. Fifth, verification of the robustness of the EFA method using k-means was applied. EFA and k-means analyses were conducted within the Statistica Version 14.0 software framework.

The EFA method is used to allow for a certain deviation from an internal element. This is significant since this relationship may result from the existence of one or many common factors that are connected by way of features (i.e., variables) from the analyzed object (i.e., stock exchange in a country). Specifically, EFA reveals the common latent factors responsible for the behavior of the features in question. Hence, in this study, EFA was identified as appropriate since it is based on the assumption that there are hidden common factors in the initial set of features. Moreover, after several latent factors were isolated using EFA, it was necessary to use an appropriate classification method in the next stage of the study. The k-means method was chosen because it consists of reducing a large number of variables to a few basic ones. This allows for the easy orientation of a given phenomenon as well as the ability to draw general conclusions. The use of the k-means method made it possible to establish a typology in terms of the studied objects and to define homogeneous objects of analysis, in which it was easier to isolate systematic factors and possible cause-and-effect relationships.

3.1. Selection of Stock Exchanges

All African exchanges were considered in the initial selection. However, due to data access and the reliability of data sources, the following two principal criteria were applied: (1) the total market capitalization of an exchange needed to be over USD 1 billion—defined as CAP, and (2) the number of listed companies in an exchange must be above 20—defined as LIST. By applying these criteria, the research aligned itself with Kalinowski's [46] premise in which larger exchanges are able to show support for sustainable business operations in terms of "differential stock market sustainability support level" [46]. It should be acknowledged that sustainable development is particularly important for foreign capital and responsible investments. In light of this, it was decided not to divide domestic capital and FDI as it did not alter the grouping of exchanges or the foreign capital due to low engagement of capital flows. An empirical analysis was performed on the selected sample of 15 stock exchanges in Africa (Table 1, Figure 1—right) using five-year interval data, i.e., 2016–2020, derived from Q1 of 2021 from (1) WFE and (2) ASEA. Note, even though the data finishes at the end of 2020, i.e., one year into the COVID-19 pandemic, the study is oriented to prepandemic levels. Moreover, ASEA data is generally broader ranged but not as up to date as WFE, and WFE data is consistent with the World Bank database (even though many experts allege the 2021 closure of the "Doing Business" report compromised World Bank data at the time [72–74]). In the case of the Ghana Stock Exchange (GSE), inclusion was possible by gathering the data directly from the stock exchange report. However, some exchanges were excluded simply because they did not meet both principal criteria.

Table 1. Research sample of 15 stock exchanges in Africa.

Abbreviation	Country	Stock Exchange Full Name
BRVM	Ivory Coast	Bourse Régionale des Valeurs Mobilières
BSE	Botswana	Botswana Stock Exchange
BVMT	Tunisia	Tunis Stock Exchange
CasaSE	Morocco	Casablanca Stock Exchange
DSE	Tanzania	Dar es Salaam Stock Exchange
EGX	Egypt	The Egyptian Exchange
GSE	Ghana	Ghana Stock Exchange
JSE	South Africa	Johannesburg Stock Exchange Ltd.
KSE	Sudan	Khartoum Stock Exchange
LuSE	Zambia	Lusaka Stock Exchange
MERJ	Seychelles	MERJ Exchange Ltd.
NSEK	Kenya	Nairobi Securities Exchange
NSE	Nigeria	Nigerian Stock Exchange
NSX	Namibia	Namibian Stock Exchange
SEM	Mauritius	Stock Exchange of Mauritius

Source: Assessment based on WFE, the World Bank, and ASEA stock exchange reports.

3.2. Variables and Measures Selection

In the study set, 22 variables were reduced to six categories of measures. The variables were defined both on the basis of SSEI criteria and on the authors' own assessment, i.e., formulated on the basis of the literature review. The two quantitative variables are described in the previous subsection. The next four measures, containing five variables each, are of qualitative nature. These measures include the following categories: market tools for sustainability (MARK), stock exchange partnerships for sustainability (PART), stock exchange sustainability communication (COM), and ESG guidance for issuers and investors (GUID). The first qualitative measure refers to specific tools related to a sustainable capital market and is perceived as directly supporting the implementation of sustainable development (Table 2).

Table 2. Market tools for sustainability.

Variable	Supportive Literature
ESG and sustainability indices	ASEA-SWG [45]
ESG as a listing rule	Maltais and Nykvist [10]
ESG or sustainability bonds	Slager [75]
ESG reporting obligation or requirements for issuers	SSEI [43,76]
Small and medium-sized enterprises' listings platform	WFE [77]; WFE and UNCTAD [78]

Next, two qualitative measures infer the stock exchange's commitment to sustainable development via the promotion and implementation of its operation as an economic entity. Stock exchanges by themselves affect the environment and society and, therefore, need to be managed in terms of minimizing negative outcomes while supporting value creation [47]. They need to incorporate various steps to be more responsible and support sustainable development by setting good practices of commitment [69]. The first of the two is participation in sustainability-oriented initiatives and stakeholder cooperation (Table 3). The second measure refers to the idea of "leading by example," which covers the communication of specific, internal ESG activities undertaken by the stock exchange as an organization (Table 4). The last qualitative measure refers to the soft tools of implementing sustainability principles as well as the dedicated entities present on the stock exchange (Table 5).

Table 3. Stock exchange partnership for sustainability.

Variable	Supportive Literature
Participation in Sustainable Stock Exchange Initiative	AccountAbility [79]
Membership in World Federation for Exchanges	ASEA-SWG [45]
Membership in African Securities Exchanges Association	SSEI [43,76]
Participation in other initiatives related to the financial market and dealing with issues of sustainability (e.g., Marrakech Pledge) and initiatives dedicated to sustainable development support (e.g., UN Global Compact)	UN Global Compact [80]; WFE [44]
Platform for cooperation with stock exchange stakeholders	WFE and UNCTAD [78]

Table 4. Stock exchange sustainability communication.

Variable	Supportive Literature
Sustainability reporting or ESG issues in annual report of stock exchange	ASEA-SWG [45]; Buchholtz and Carroll [81]
Separate tab on stock exchange website, dedicated to ESG and sustainability issues	Gomez [82]; Hetze and Winistörfer [83]
Published documents on sustainability and corporate social responsibility issues (e.g., policies, strategies, codes of conduct, etc.)	GRI [84]; ISO [85]; Kaptein and Schwartz [86]
References to sustainability in the declaration of stock exchanges (i.e., mission, vision, and values statements)	Mansi et al. [87]; SSEI [43]
Published information on the social initiatives of stock exchanges	WFE [44,77]

Table 5. ESG guidance for issuers and investors.

Variable	Supportive Literature
Written guidance on responsible investment	ASEA-SWG [45]; Khemir et al. [88]
Written guidance on ESG reporting	Kyereboah-Coleman [89]; Park [65]
ESG trainings for investor and issuers	SSEI [43,76]; WFE [77]
Written guidance on ESG bonds issuing	WFE and UNCTAD [78]
Published governance standards including ESG issues	Zhan and Santos-Paulino [13]

Quantitative data for the period of 2016–2020 were attained from Q1 of 2021, i.e., after the first year of the pandemic. Qualitative variables, for the purpose of this study, were collected through the analysis of the following:

- Prepandemic research results on the sustainability of stock exchanges, published in 2018 and 2019 by SSEI, WFE, and ASEA;

- Information concerning ESG, published by individual exchanges on their websites from Q1 of 2021; and
- Information on the membership of exchanges in initiatives for capital market sustainability—based on data from each particular initiative website.

3.3. Normalization Process

Quantitative variables and the set of qualitative variables were normalized on an ordinal scale (i.e., from one to five) (Table 6). The size of the stock exchange, determined by its capitalization and expressed by the number of listed companies, was ordered in the ordinal scale using percentiles. The four qualitative measures, based on qualitative variables, consist of five single indicator variables each (i.e., dummy variables) and indicate whether certain conditions are true. Every qualitative variable has a value of one when conditions hold and a value of zero when they do not. This approach is justified, as a more in-depth assessment may pose as too subjective. The general conclusion is that the best outputs have measures that refer to stock exchange partnerships for sustainability involvement. Such tools as the small- and medium-sized enterprise listings platform or sustainable "green" bonds are still poorly implemented at the individual case level. Moreover, supporting initiatives, such as training and written guidance on responsible investment, ESG reporting, and governance standards, are often poorly compiled and lack completeness.

Table 6. Normalized values from one (i.e., low) to five (i.e., high) for selected stock exchanges in Africa.

Stock Exchange [†]	CAP	LIST	MARK	PART	COM	GUID
BRVM	2	3	1	4	3	1
BSE	4	1	1	4	4	4
BVMT	3	4	1	4	3	1
CasaSE	5	4	2	4	3	2
DSE	2	1	2	3	3	2
EGX	4	5	4	5	5	5
GSE	3	2	1	2	1	1
JSE	5	5	5	5	5	5
KSE	1	3	1	2	1	1
LuSE	1	1	1	3	1	1
MERJ	1	2	1	3	2	1
NSEK	3	3	1	4	4	4
NSE	4	5	4	4	4	4
NSX	5	2	5	4	3	1
SEM	2	4	3	5	3	2

[†] CAP—total equity market capitalization, LIST—total number of listed companies, MARK—market tools for sustainability, PART—stock exchange partnership for sustainability, COM—stock exchange sustainability communication, GUID—ESG guidance for issuers and investors.

4. Results and Discussion

4.1. Exploratory Factor Analysis

The process of EFA assessed the sets of six measures, based on the 22 variables, by transforming the two underlying latent factors (i.e., soft and hard) by way of the linear interrelationships via the output measures. Each factor is determined by the relation pattern between measures and dominated by variables with high loads. The factors identify a structure of variability and show the relationship among the variables, identifying any underlying commonalities across the sample of observed African exchanges. The obtained raw factors in EFA were rotated using an orthogonal method called varimax rotation, i.e., an algorithm to determine the dimensions of the factors where one variable loads highly on one particular factor but loads less on the other [90]. As a result, the final result simplifies the interpretation of factors, where one factor has high loadings on some variables

and low on others. The soft factor is determined by the following measures with the highest loads: PART, COM, and GUID. These measures describe soft, indirect sustainability support provided by the given stock exchanges. Contrarywise, the hard factor is defined by CAP, LIST, and MARK and supports hard, direct measures in favor of sustainability measures. In short, utilizing EFA aided in the robustness of performance measures and overall study checks. The soft factor explains 44.1% complete volatility of all six measures, while the hard factor explains 34%. Both factors determine 78.1% of the whole variability (Table 7). Due to the large values of the specified soft factor and hard factor, a further analysis was performed. The values of factor loadings for both factors were used to classify the analyzed exchanges (Figure 2).

Table 7. EFA factor loadings after varimax rotation.

Measure	Soft Factor	Hard Factor
CAP	0.418	0.722 *
LIST	0.454	0.586 **
MARK	0.280	0.880 *
PART	0.743 *	0.469
COM	0.900 *	0.375
GUID	0.908 *	0.198
Variance explained	*2.647*	*2.039*
Percentage of total variance	*44.1%*	*34.0%*

* significance level at 0.7, ** significance level at 0.6.

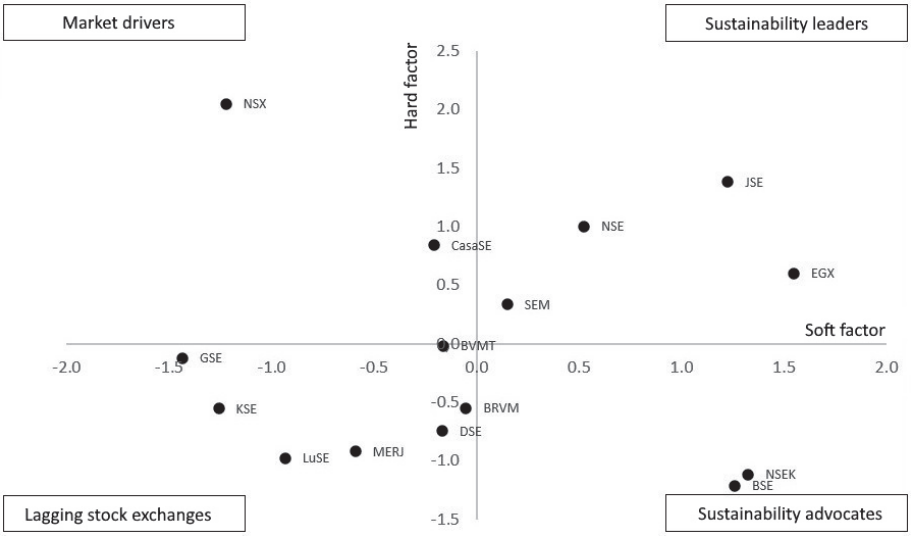


Figure 2. Scatter plot of the stock exchanges in Africa based on EFA.

Based on EFA, the leading group with both the greatest factors and best performance measures in terms of sustainability leaders were JSE, NSE, the Egyptian Exchange (EGX), and the Stock Exchange of Mauritius (SEM). JSE, NSE, and EGX represent the greatest quantitative market performance. JSE, with over 330 listed companies and a market capitalization of around USD 1 trillion, is by far the best-matured stock exchange in Africa and tops all other exchanges on the continent. This group also has a strong position in terms of sustainable tools, both in their organizational and market nature. The only exchange that lags in performance is SEM, characterized by low capitalization (i.e., per USD), even though

it still includes a relatively high number of companies and good results in the assessment of the potential for sustainable development (i.e., via the qualitative variables). A deep study of all SEM trading confirms a generally low contribution to sustainability, which corresponds to its smaller size; however, since it had a relatively large number of tools for SDGs, it was included in the leading group based on EFA.

The largest group (i.e., the lagging group) of stock exchanges presented rather low values of both soft factors and hard factors, consisting of Tunis Stock Exchange (BVMT), GSE, Khartoum Stock Exchange (KSE), Lusaka Stock Exchange (LuSE), MERJ Exchange Limited (MERJ), Dar es Salaam Stock Exchange (DSE), and Bourse Régionale des Valeurs Mobilières (BRVM). This group can be described by relatively low outputs of all measures except for PART, which are general-level outputs for all exchanges. These exchanges have less than USD 10 billion of capitalization and do not exceed 55 listed companies, except for BVMT, which had 80. BVMT is not consistent with the other exchanges in this group since LIST and PART measures perform better (i.e., four out of five) while two other measures (i.e., COM and GUID) perform very poorly. The two remaining groups, with average results, include two stock exchanges each. The group presenting low outputs with a soft factor and stronger outputs with a hard factor (i.e., market drivers) include very diverse exchanges: Casablanca Stock Exchange (CasaSE) and Namibia Stock Exchange (NSX). CasaSE, in recent periods, averaged over USD 55 billion (and peaked at USD 65 billion) of capitalization with 76 listed companies. However, being one of the strongest stock exchanges in Africa, CasaSE does not promote advanced sustainability supporting tools. NSX, which is more than twice as high as CasaSE in capitalization and has only 40 listed companies, provides more advanced tools supporting sustainability, including green bonds. The last group of exchanges, i.e., sustainability-friendly exchanges, perform well with soft measures but have lower outputs with hard measures, including the Nairobi Securities Exchange (NSEK) and Botswana Stock Exchange (BSE). BSE is definitely stronger in USD-denominated capitalization but with half (i.e., 32) of the companies listed compared to NSEK (i.e., 62). The remaining four measures have the same value.

4.2. Robustness Check of the EFA Classification

After a thorough analysis of the EFA classification results, two of the exchanges show proximity to both axes (i.e., SEM in the leading group and BVMT in the second lagging group). Due to an analysis of the qualitative measures, it was decided to verify the results using a different classification process, i.e., a robustness check. A non-hierarchical k-means analysis (i.e., developed by MacQueen [91] in 1967) with four clusters (i.e., K = 4) determined a priori with stock exchanges classified to the clusters based upon the smallest distance to the cluster mean [92] (Figure 3). JSE, NSE, and EGX were classified together in the leading group, but the SEM outlier migrated. Clustering outputs were examined for two, three, and four groups, and in every case, those three leading exchanges stayed together while the rest migrated depending on the cluster obtained. A potential explanation for the difference in the grouping of SEM and BVMT under the EFA and k-means method may arise from the fact that each classification is an image of reality, and the results obtained depend on the algorithm used.

The second method allowed us to analyze the robustness of the EFA classification of the exchanges into four groups, as in Figure 2. Some of the exchanges from different EFA groups are quite close, where the division is not strict depending on the adopted criteria and may move to other groups (i.e., depending on the adopted stock exchange features). The first feature that differs is capitalization, which weighs heavily in the classification. As a second measure, market tools for sustainability were applied. Both measures constitute the hard factor. In the case of BVMT, capitalization determined the transfer to market drivers, while SEM migrated to the same group due to lower capitalization and weaker activity in the field of sustainability, including dedicated market tools. The k-means results show that the exchanges mentioned can indeed migrate to other groups (Table 8).

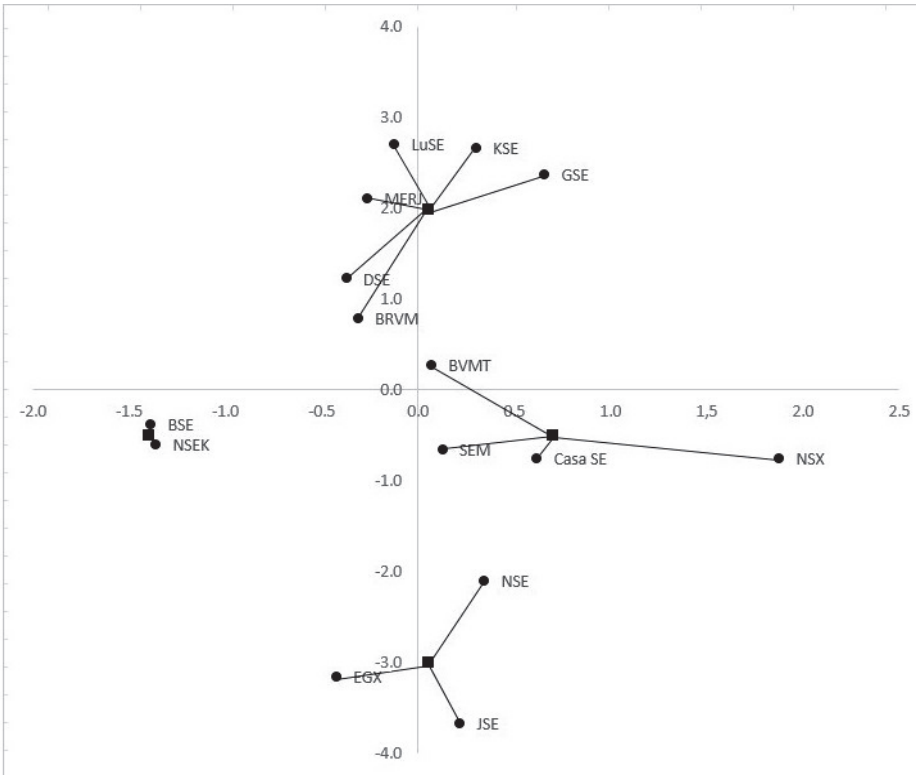


Figure 3. Scatter plot of the stock exchanges in Africa based on k-means.

Table 8. Comparison of the clusters obtained using EFA and k-means.

Cluster	EFA	K-Means
1	BRVM DSE GSE KSE LuSE MERJ **BVMT**	BRVM DSE GSE KSE LuSE MERJ
2	BSE NSEK	BSE NSEK
3	CasaSE NSX	**BVMT** CasaSE NSX **SEM**
4	EGX JSE NSE **SEM**	EGX JSE NSE

The two exchanges described above (i.e., BVMT and SEM) have moved to other groups. The results of classification using the k-means method were generally consistent with the results of the EFA method, except for the two outliers, which were classified better. In all, the application of the k-means method to the clas sification of the exchanges gave

convergent results with the classification obtained using EFA. This is evidenced, among others, by the small number of inversions.

4.3. Sustainable Stock Market Finance: General Discussion

In this study, different measures have been used to address sustainable stock market finance. As such, many studies address sustainability by the use of proxies. Gong et al. [93], for example, studied changes in stock return by examining companies with different levels of climate risk during the presidential election cycle in the United States. They found the election cycle did act as an "indicator of international political uncertainty [and that it directly] affects the riskiness of firms with high exposure to climate risk" [93]. It can be inferred that the sustainability approach does not directly provide a higher stock return; however, globally, it can indirectly influence company risk and lower the cost of capital. Venturini [94] analyzes climate risk drivers on the equity market to examine which climate risk affects stock returns. Santi [95], expanding on this, notes the overreaction to climate risk by investors as well as how the investor learning process and corrective mispricing of stocks influence decisions and long-term sustainability. Specifically, sustainable stock market finance in Africa is best when it is synchronized geographically via the emerging markets' sustainability index and when it incorporates the related risk diversification throughout the continent's exchanges [96].

To better understand the different processes of sustainable stock market finance, a number of methods have been applied. For instance, k-means as a method for stock exchange analysis has been utilized in a variety of ways, including modeling and optimization of stock portfolios; choosing prospective sets of assets for portfolios; and influencing changes in stock prices by financial statements, grouping stocks by return, and risk criteria [97–100]. Another application is the classification of stock market indices as laid out by Chmielewski et al. [101]. They highlight the classification of listed companies in terms of ESG criteria, i.e., "the significance of forming clusters and linking sustainability practices with performance characteristics" [102]. Kishan and Kiran [103], correspondingly, focus on SDG 8, which supports small- and medium-sized enterprises (SMEs) as one of the five SDGs identified as an area of action for sustainability by stock exchanges. They analyze the performance of Indian indices dedicated to SMEs and show how a majority of stock exchanges that have adopted SME listings generate "better returns with slightly [higher] volatility" [103]. In terms of understanding clustering effects, a comparative analysis of European stock exchanges shows that exchanges with similar characteristic features tend to cluster in terms of market size, equity trading, and bonds [104]. This parallels findings in this study by way of research methodology and validity. A similar approach, with a breakdown of pillars and components, was launched by the Global Entrepreneurship Development Institute to harmonize the digital and entrepreneurship ecosystems into one platform [105,106]. They state, "for technology to be introduced successfully, the digital ecosystem and the entrepreneurial ecosystem must be developed simultaneously" [105]. Likewise, it can be argued that stock exchanges' soft factors and hard factors need to be developed at the same time for the best sustainability results.

The novelty of this study is that, for the first time, the specific method and approach employed have been used to examine stock exchanges. The analysis of broad but general aspects of the sustainability approach looks at what instruments and practices African stock exchanges use to perform sustainability as well as how they deal with international requirements and investor needs. The examined stock exchanges parallel organizations in that the study is developed via "rules and rule setters." From the organizational side, memberships and participation in international initiatives are considered alongside communication through reporting and published declarations. In terms of rules for listed companies, the consider instruments aimed at sustainability and supporting initiatives of stock exchanges to support and motivate companies, e.g., training, guidance, and standards, are applied. The research duplicates aspects of the Chmielewski et al. [101] study in that we differentiate exchanges by way of size and capital performance. The contribution of this

study is twofold. First, it adds to the literature on general stock exchange sustainability performance. Second, it contributes to the methodological analysis of stock exchanges based on qualitative dimensions. This is exemplified by the grouping of stock exchanges in terms of their sustainability (i.e., approach and performance). At length, the research expands the knowledge base on African stock exchange sustainability and informs whether they have sustainability tools and practices. The novelty of performing general sustainability advocacy of such exchanges also reinforces support of international assets invested in Africa.

5. Conclusions

Stock market research is crucial for understanding the role of the capital market in developing the concept of sustainable development in the real economy. The classification of the selected stock exchanges in Africa was performed to determine and compare their pre-pandemic potential to support the sustainability approach. The study is based on a multicriteria assessment of the level of commitment of stock exchanges to sustainability, taking into account not only traditionally analyzed elements (i.e., sustainable stock exchange indices and sustainable financial instruments) but also categories such as reporting and knowledge support for investors. As a result, four groups of stock exchanges were identified, providing a practical reference for the effective implementation of the sustainability approach. The research is based on a set of variables that is much broader than in previously published analyses. The systematized set of variables evaluates the exchanges using two methods: EFA and k-means. The results of the classification of the stock exchanges into four classes are, in principle, consistent. The research shows that the following stock exchanges in Africa have the greatest relative potential for implementing sustainable development: JSE, NSE, and EGX. Our findings are in agreement with theoretical and empirical research concepts in the field of the maturity of stock exchanges [37] and action-oriented sustainable development impact assessments [12,43,45,46,77,78]. The study develops the current approach to assessing exchanges in terms of ESG through the use of a multidimensional approach. It combines existing knowledge into one approach aiming to group and compare stock exchanges and tries to fill a significant research gap in assessing the impact of stock exchanges on sustainable development.

The fundamental limitation of a satisfactory sample selection of exchanges and their fair distribution due to quantitative data is the gaps in the availability of recent data, both on the websites of these institutions and in the exchange reports. (This is why, for example, the Zimbabwe Stock Exchange, with over 60 listed companies, could not be included). Moreover, another problem concerning quantitative data is its completeness and consistency, e.g., WFE has data only for some exchanges, but not all of it includes the best performance; the World Bank has WFE data even though WFE data is more recent, some data between WFE and ASEA is inconsistent, and some WFE data does not seem to confirm the rankings of the best-performing exchanges based on African financial portals. For future research, it would be worth enriching the analysis by verifying the post-pandemic stock exchanges based on the stock market development relational dimension proposed by Levine and Zervos [107], e.g., capitalization to gross domestic product and the number of listed enterprises. In the research, the authors departed from the variables based on FDI, as the share of this capital is not high; furthermore, in some countries, restrictions and limits for foreign investors have been introduced, which would require further analysis outside the purview of this study.

The difficulties related to qualitative data, i.e., the different ways in which exchanges are presented, are another limitation. In some cases, declared actions (e.g., answers provided by SSEI or ASEA) are difficult to confirm even by analyzing the content of the exchange's website. As such, the study assumes that it is sufficient to indicate an action in at least one of the sources (i.e., reports from SSEI or ASEA or content of the exchange's website). Another limitation derives from the approach to scaling of variables. For most variables, dummy variables were adopted, which only confirm the fact that the tool is

implemented by the given exchange without assessing its quality—the assessment of instruments on the basis of their intrinsic characteristics can be difficult and subject to the risk of misinterpretation. Setting these limitations aside, the research demonstrates the importance of identifying key sustainability drivers and examines the materiality of the drivers within an African context. These drawbacks should be considered as future goals to better the research and, ultimately, aid in defining future ESG-based comparative and growth potential research of stock exchanges in Africa. At length, this fiscal maturity can be fundamental to increasing economic and business development via the SDGs initiative—continent-wide.

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References

1. Meadows, D.H.; Meadows, D.L.; Randers, J.; Behrens, W.W. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*; Universe Books: New York, NY, USA, 1972; ISBN 978-0-87663-165-2.
2. World Bank. *World Development Report 2000/2001: Attacking Poverty*; Oxford University Press: New York, NY, USA, 2001.
3. UNEP. *Global Environment Outlook 2000*; United Nations Environment Programme: Nairobi, Kenya, 1999.
4. Elkington, J. Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *Calif. Manag. Rev.* **1994**, *36*, 90–100. [CrossRef]
5. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*; Capstone: Oxford, UK, 1997; ISBN 1-900961-27-X.
6. Cirella, G.T.; Tao, L. The Index of Sustainable Functionality: An Application for Measuring Sustainability. *Int. J. Humanit. Soc. Sci.* **2009**, *3*, 268–274.
7. Kyove, J.; Streltsova, K.; Odibo, U.; Cirella, G.T. Globalization Impact on Multinational Enterprises. *World* **2021**, *2*, 216–230. [CrossRef]
8. Oniszczuk-Jastrząbek, A.; Czermański, E.; Cirella, G.T. Sustainable Supply Chain of Enterprises: Value Analysis. *Sustainability* **2020**, *12*, 419. [CrossRef]
9. UN United Nations Sustainable Development Goals. Available online: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (accessed on 3 May 2019).
10. Maltais, A.; Nykvist, B. Understanding the Role of Green Bonds in Advancing Sustainability. *J. Sustain. Financ. Investig.* **2020**, 1–20. [CrossRef]
11. UNCTAD. *Promoting Entrepreneurship for Sustainable Development: A Selection of Business Cases from the Empretec Network*; United Nations Conference on Trade and Development; United Nations Publication: New York, NY, USA, 2017.
12. UNCTAD. *International Production beyond the Pandemic: 30th Anniversary Edition*; World Investment Report; United Nations: Geneva, Switzerland, 2020; ISBN 978-92-1-112985-4.
13. Zhan, J.X.; Santos-Paulino, A.U. Investing in the Sustainable Development Goals: Mobilization, Channeling, and Impact. *J. Int. Bus. Policy* **2021**, *4*, 166–183. [CrossRef]
14. *Sustainable Human–Nature Relations: Environmental Scholarship, Economic Evaluation, Urban Strategies*; Cirella, G.T. (Ed.) Advances in 21st Century Human Settlements; Springer: Singapore, 2020; ISBN 978-981-15-3048-7.
15. Manasseh, C.O.; Mathew, T.E.; Ogbuabor, J.E. Investigating the Nexus between Institutional Quality and Stock Market Development in Nigeria: An Autoregressive Distributed Lag (ARDL) Approach. *Afr. Dev. Rev.* **2017**, *29*, 272–292. [CrossRef]
16. Bodie, Z.; Kane, A.; Marcus, A. *Investments*, 12th ed.; McGraw-Hill: New York, NY, USA, 2021; ISBN 978-1-260-01383-2.
17. Alley, I. Private Capital Flows and Economic Growth of Sub-Saharan African Countries. *Afr. Dev. Rev.* **2015**, *27*, 469–483. [CrossRef]

18. Gemeda, B.S.; Abebe, B.G.; Paczoski, A.; Xie, Y.; Cirella, G.T. What Motivates Speculators to Speculate? *Entropy* **2019**, *22*, 59. [CrossRef] [PubMed]
19. Pelizzo, R.; Araral, E.; Pak, A.; Xun, W. Determinants of Bribery: Theory and Evidence from Sub-Saharan Africa. *Afr. Dev. Rev.* **2016**, *28*, 229–240. [CrossRef]
20. African Development Bank African Economic Outlook 2020. Available online: https://www.afdb.org/en/news-keywords/african-economic-outlook-2020 (accessed on 3 March 2023).
21. UN Economic Commission for Africa. *Africa Regional Report on the Sustainable Development Goals*; United Nations Economic Commission for Africa: Addis Ababa, Ethiopia, 2015.
22. *Uncertainty Shocks in Africa: Impact and Equilibrium Strategies for Sound Economic and Social Development*; Cirella, G.T. (Ed.) Advances in African Economic, Social and Political Development; Springer: Cham, Germany, 2023; ISBN 978-3-031-21884-2.
23. UNCTAD. *Structural Transformation and Sustainable Development in Africa*; Economic Development in Africa Report; United Nations Conference on Trade and Development; United Nations Publication: New York, NY, USA, 2012; ISBN 978-92-1-055595-1.
24. Schiereck, D.; Freytag, A.; Grimm, M.; Bretschneider, W.H. *Public Corporations in Africa: A Continental Survey on Stock Exchanges and Capital Markets Performance*; Jena Economic Research Papers; Jena Economic Research: Jena, Germany, 2018.
25. Klagge, B.; Zademach, H.-M. International Capital Flows, Stock Markets, and Uneven Development: The Case of Sub-Saharan Africa and the Sustainable Stock Exchanges Initiative (SSEI). *Z. Für Wirtsch.* **2018**, *62*, 92–107. [CrossRef]
26. Marbuah, G. *Scoping the Sustainable Finance Landscape in Africa: The Case of Green Bonds*; Stockholm Sustainable Finance Centre: Stockholm, Sweden, 2020.
27. Ncube, G.; Mingiri, K.F. Stock Market Integration in Africa: The Case of the Johannesburg Stock Exchange and Selected African Countries. *IBER* **2015**, *14*, 367–386. [CrossRef]
28. Odera, O. Theoretical Issues on the African Stock Markets and Portfolio Performance. *J. Econ. Int. Financ.* **2012**, *4*, 19–28. [CrossRef]
29. Andrianaivo, M.; Yartey, C.A. Understanding the Growth of African Financial Markets. *Afr. Dev. Rev.* **2010**, *22*, 394–418. [CrossRef]
30. Raubenheimer, H. *African Capital Markets: Challenges and Opportunities*; CFA Institute Research Foundation Briefs: Charlottesville, VA, USA, 2019; ISBN 978-1-944960-87-2.
31. Abdulkadir, R.I.; Abdullah, N.A.H.; Wong, W.-C. Dividend Payment Behaviour and Its Determinants: The Nigerian Evidence. *Afr. Dev. Rev.* **2016**, *28*, 53–63. [CrossRef]
32. Lucas, R.E. On the Mechanics of Economic Development. *J. Monet. Econ.* **1988**, *22*, 3–42. [CrossRef]
33. Beck, T.; Levine, R. Stock Markets, Banks, and Growth: Panel Evidence. *J. Bank. Financ.* **2004**, *28*, 423–442. [CrossRef]
34. Boubakari, A.; Jin, D. The Role of Stock Market Development in Economic Growth: Evidence from Some Euronext Countries. *Int. J. Financ. Res.* **2010**, *1*, 14–20. [CrossRef]
35. El Menyari, Y. Financial Development, Foreign Banks and Economic Growth in Africa. *Afr. Dev. Rev.* **2019**, *31*, 190–201. [CrossRef]
36. King, R.G.; Levine, R. Finance and Growth: Schumpeter Might Be Right. *Q. J. Econ.* **1993**, *108*, 717–737. [CrossRef]
37. Levine, R. *Finance and Growth: Theory and Evidence*; Working Paper Series; National Bureau of Economic Research: New York, NY, USA, 2004.
38. Pradhan, R.P.; Arvin, M.; Norman, N.R.; Hall, J.H. The Dynamics of Banking Sector and Stock Market Maturity and the Performance of Asian Economies: Time Series Evidence. *J. Econ. Adm. Sci.* **2014**, *30*, 16–44. [CrossRef]
39. Assefa, T.A.; Mollick, A.V. Financial Development and Economic Growth in Africa. *J. Afr. Bus.* **2017**, *18*, 320–339. [CrossRef]
40. Bonuedi, I.; Kamasa, K.; Boateng, E. The Growth Effects of the Bulging Economically Active Population in Sub-Saharan Africa: Do Institutions Matter? *Afr. Dev. Rev.* **2019**, *31*, 71–86. [CrossRef]
41. UNCTAD. *Economic Development in Africa Report 2017: Tourism for Transformative and Inclusive Growth*; Economic Development in Africa Report; United Nations Conference on Trade and Development; United Nations Publication: New York, NY, USA, 2017.
42. Busch, T.; Bauer, R.; Orlitzky, M. Sustainable Development and Financial Markets: Old Paths and New Avenues. *Bus. Soc.* **2016**, *55*, 303–329. [CrossRef]
43. SSEI 10 Years of Impact and Progress: Sustainable Stock Exchanges 2009–2019. Available online: https://sseinitiative.org/wp-content/uploads/2019/12/SSE-10-year-impact-report.pdf (accessed on 3 March 2023).
44. WFE WFE Annual Sustainability Survey 2019. Available online: https://www.world-exchanges.org/storage/app/media/WFE%20Annual%20Sustainability%20Survey%202019%20-%20Final%2023.04.2019.pdf (accessed on 3 March 2023).
45. *ASEA-SWG Sustainability Progress Report*; African Securities Exchanges Association: Cairo, Egypt, 2019.
46. Kalinowski, M. Stock Exchanges Sustainability Support Assessment. *Copernic. J. Financ. Account.* **2014**, *3*, 37–48. [CrossRef]
47. SSEI. WFE How Exchanges Can Embed Sustainability within Their Operations: A Blueprint to Advance Action. Available online: https://sseinitiative.org/wp-content/uploads/2019/12/SSE-WFE-Embedding-Sustainability-Report.pdf (accessed on 3 March 2023).
48. Lamichhane, S.; Eğilmez, G.; Gedik, R.; Bhutta, M.K.S.; Erenay, B. Benchmarking OECD Countries' Sustainable Development Performance: A Goal-Specific Principal Component Analysis Approach. *J. Clean. Prod.* **2021**, *287*, 125040. [CrossRef]

49. Swiss Re Home Page. Available online: https://www.swissre.com/ (accessed on 15 September 2021).
50. Marcinkowska, M. Odpowiedzialne Przedsiębiorstwo Na Rynku Kapitałowym-Czyli o Giełdowych Indeksach Zrównoważonego Rozwoju (A Responsible Company on the Capital Market-or about Stock Exchange Indices of Sustainable Development). In *Przedsiębiorstwo na Rynku Kapitałowym (Enterprise on the Capital Market)*; Duraj, J., Ed.; WUŁ: Łódź, Poland, 2010; pp. 123–144.
51. Chatterji, A.; Levine, D. Breaking down the Wall of Codes: Evaluating Non-Financial Performance Measurement. *Calif. Manag. Rev.* **2006**, *48*, 29–51. [CrossRef]
52. Sikacz, H. Porównanie wyników wybranych indeksów giełdowych przedsiębiorstw społecznie odpowiedzialnych na świecie (Comparison of the results of selected stock indices of socially responsible enterprises in the world). *Comp. Results Some Stock Mark. Indices List. Corp. Soc. Responsible World* **2016**, *4*, 213–227.
53. Slager, R.; Chapple, W. Carrot and Stick? The Role of Financial Market Intermediaries in Corporate Social Performance. *Bus. Soc.* **2016**, *55*, 398–426. [CrossRef]
54. Vives, A.; Wadhwa, B. Sustainability Indices in Emerging Markets: Impact on Responsible Practices and Financial Market Development. *J. Sustain. Financ. Investig.* **2012**, *2*, 318–337. [CrossRef]
55. Yilmaz, M.K.; Aksoy, M.; Tatoglu, E. Does the Stock Market Value Inclusion in a Sustainability Index? Evidence from Borsa Istanbul. *Sustainability* **2020**, *12*, 483. [CrossRef]
56. Deng, X.; Cheng, X. Can ESG Indices Improve the Enterprises' Stock Market Performance?—An Empirical Study from China. *Sustainability* **2019**, *11*, 4765. [CrossRef]
57. Lean, H.H.; Pizzutilo, F. Performances and Risk of Socially Responsible Investments across Regions during Crisis. *Int. J. Financ. Econ.* **2021**, *26*, 3556–3568. [CrossRef]
58. Nitani, M.; Carriere, B.; Bleackley, A. Recognizing Corporate Citizenship: Market Reactions. *J. Sustain. Financ. Investig.* **2015**, *5*, 85–102. [CrossRef]
59. Ho, M. The Social Construction Perspective on ESG Issues in SRI Indices. *J. Sustain. Financ. Investig.* **2013**, *3*, 360–373. [CrossRef]
60. UNCTAD. *World Investment Report 2020*; United Nations: New York, NY, USA, 2020.
61. Deschryver, P.; de Mariz, F. What Future for the Green Bond Market? How Can Policymakers, Companies, and Investors Unlock the Potential of the Green Bond Market? *J. Risk Financ. Manag.* **2020**, *13*, 61. [CrossRef]
62. Inderst, G.; Stewart, F. *Incorporating Environmental, Social and Governance (ESG) Factors into Fixed Income Investment*; World Bank Group Publication: New York, NY, USA, 2018.
63. Jones, P.; Comfort, D. Sustainability Bonds and Green Bonds in the Retail Sector. *Int. J. Sales Retail. Mark.* **2020**, *9*, 37–43.
64. UNCTAD. *Investment Policy Framework for Sustainable Development*; United Nations Conference on Trade and Development; United Nations Publication: New York, NY, USA, 2015.
65. Park, S. Investors as Regulators: Green Bonds and the Governance Challenges of the Sustainable Finance Revolution. *Stanf. J. Int. Law* **2018**, *54*, 1–47.
66. Russo, A.; Mariani, M.; Caragnano, A. Exploring the Determinants of Green Bond Issuance: Going beyond the Long-Lasting Debate on Performance Consequences. *Bus. Strategy Environ.* **2021**, *30*, 38–59. [CrossRef]
67. Erhart, S. Exchange-Traded Green Bonds: Discussion Paper 2018. Available online: https://www.thejei.com/wp-content/uploads/2018/10/Exchange-Traded-Green-Bonds-by-Szilard-Erhart.pdf (accessed on 10 January 2023).
68. Berensmann, K. *Upscaling Green Bond Markets: The Need for Harmonised Green Bond Standards | Green Finance Platform*; Briefing Paper, No. 12; Deutsches Institut für Entwicklungspolitik: Bonn, Germany, 2017.
69. SSEI How Stock Exchanges Can Grow Green Finance. Available online: https://sseinitiative.org/publication/how-stock-exchanges-can-grow-green-finance/ (accessed on 3 March 2023).
70. *LSEG Africa Advisory Group Developing the Green Bond Market in Africa*; London Stock Exchange Group: London, UK, 2018.
71. Tolliver, C.; Keeley, A.R.; Managi, S. Green Bonds for the Paris Agreement and Sustainable Development Goals. *Environ. Res. Lett.* **2019**, *14*, 064009. [CrossRef]
72. Kar, S.; Pritchett, L.; Roy, S.; Sen, K. Doing Business in a Deals World: The Doubly False Premise of Rules Reform. *J. Econ. Policy Reform* **2022**, *25*, 361–387. [CrossRef]
73. Thomas, D. Doing Business Index Faces Credibility Crisis. Available online: https://african.business/2021/02/technology-information/doing-business-index-faces-credibility-crisis (accessed on 16 March 2023).
74. Nicola, F.G. Scandal Involving World Bank's "Doing Business" Index Exposes Problems in Using Sportslike Rankings to Guide Development Goals. Available online: http://theconversation.com/scandal-involving-world-banks-doing-business-index-exposes-problems-in-using-sportslike-rankings-to-guide-development-goals-169691 (accessed on 16 March 2023).
75. Slager, R. SRI Indices and Responsible Corporate Behavior: A Study of the FTSE4Good Index. *Bus. Soc.* **2015**, *54*, 386–405. [CrossRef]
76. SSEI 2018 Report on Progress. Available online: https://sseinitiative.org/wp-content/uploads/2018/10/SSE_On_Progress_Report_FINAL.pdf (accessed on 3 March 2023).
77. WFE WFE Sustainability Principles. Available online: https://www.world-exchanges.org/storage/app/media/research/Studies_Reports/2018/WFE%20Sustainability%20Principles%20October%202018.pdf (accessed on 3 March 2023).
78. WFE; UNCTAD. *The Role of Stock Exchanges in Fostering Economic Growth and Sustainable Development*; World Federation for Exchanges and United Nations Conference on Trade and Development, United Nations Publication: Geneva, Switzerland, 2017.

79. AccountAbility AA1000–Stakeholder Engagement Standard. Available online: https://www.accountability.org/standards/ (accessed on 3 March 2023).
80. UN Global Compact Homepage. Available online: https://unglobalcompact.org/ (accessed on 3 March 2023).
81. Buchholtz, A.; Carroll, A.B. *Business and Society*, 7th ed.; Cengage Learning: London, UK, 2009; ISBN 978-0-324-58065-5.
82. Gomez, L.M. CSR Communication Through the Lens of New Media. In *Sustainability and Social Responsibility of Accountability Reporting Systems: A Global Approach*; Çalıyurt, K.T., Said, R., Eds.; Accounting, Finance, Sustainability, Governance & Fraud: Theory and Application; Springer: Singapore, 2018; pp. 197–217. ISBN 978-981-10-3212-7.
83. Hetze, K.; Winistörfer, H. CSR Communication on Corporate Websites Compared across Continents. *Int. J. Bank Mark.* **2016**, *34*, 501–528. [CrossRef]
84. GRI Consolidated Set of GRI Sustainability Reporting Standards 2020. Available online: https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/ (accessed on 3 March 2023).
85. ISO ISO 26000—Social Responsibility. Available online: https://www.iso.org/iso-26000-social-responsibility.html (accessed on 3 March 2023).
86. Kaptein, M.; Schwartz, M.S. The Effectiveness of Business Codes: A Critical Examination of Existing Studies and the Development of an Integrated Research Model. *J Bus Ethics* **2008**, *77*, 111–127. [CrossRef]
87. Mansi, M.; Pandey, R.; Ghauri, E. CSR Focus in the Mission and Vision Statements of Public Sector Enterprises: Evidence from India. *Manag. Audit. J.* **2017**, *32*, 356–377. [CrossRef]
88. Khemir, S.; Baccouche, C.; Ayadi, S.D. The Influence of ESG Information on Investment Allocation Decisions: An Experimental Study in an Emerging Country. *J. Appl. Account. Res.* **2019**, *20*, 458–480. [CrossRef]
89. Kyereboah-Coleman, A. Corporate Governance and Shareholder Value Maximization: An African Perspective. *Afr. Dev. Rev.* **2007**, *19*, 350–367. [CrossRef]
90. Aczel, A.D. *Complete Business Statistics*, 7th ed.; McGraw-Hill: Chicago, IL, USA, 2009; ISBN 978-0-256-13894-8.
91. MacQueen, J. Some Methods for Classification and Analysis of Multivariate Observations. In *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1: Statistics*; The Regents of the University of California: Oakland, CA, USA, 1967; Volume 5.1, pp. 281–298.
92. *Data Clustering: Algorithms and Applications*, 1st ed.; Aggarwal, C.C.; Reddy, C.K. (Eds.) Chapman and Hall/CRC: Boca Raton, FL, USA, 2013; ISBN 978-1-4665-5821-2.
93. Gong, X.; Fu, C.; Huang, Q.; Lin, M. International Political Uncertainty and Climate Risk in the Stock Market. *J. Int. Financ. Mark. Inst. Money* **2022**, *81*, 101683. [CrossRef]
94. Venturini, A. Climate Change, Risk Factors and Stock Returns: A Review of the Literature. *Int. Rev. Financ. Anal.* **2022**, *79*, 101934. [CrossRef]
95. Santi, C. Investor Climate Sentiment and Financial Markets. *Int. Rev. Financ. Anal.* **2023**, *86*, 102490. [CrossRef]
96. Boitan, I.A. Sustainable Stock Market Indices: A Comparative Assessment of Performance. *J. Res. Emerg. Mark.* **2020**, *2*, 7–14. [CrossRef]
97. Renugadevi, T.; Ezhilarasie, R.; Sujatha, M.; Umamakeswari, A. Stock Market Prediction Using Hierarchical Agglomerative and K-Means Clustering Algorithm. *Indian J. Sci. Technol.* **2016**, *9*, 1–6. [CrossRef]
98. Siregar, B.; Pangruruk, F.A. Portfolio Optimization Based on Clustering of Indonesia Stock Exchange: A Case Study of Index LQ45. *Indones. J. Bus. Anal.* **2021**, *1*, 59–70. [CrossRef]
99. Lee, M.-T.; Lee, C.L.; Lee, M.-L.; Liao, C.-Y. Price Linkages between Australian Housing and Stock Markets. *Int. J. Hous. Mark. Anal.* **2017**, *10*, 305–323. [CrossRef]
100. Nakagawa, K.; Imamura, M.; Yoshida, K. Stock Price Prediction Using K-medoids Clustering with Indexing Dynamic Time Warping. *Electron. Commun. Jpn.* **2019**, *102*, 3–8. [CrossRef]
101. Chmielewski, L.J.; Janowicz, M.; Ochnio, L.; Orłowski, A. Clusterization of Indices and Assets in the Stock Market. In *Intelligent Data Engineering and Automated Learning–IDEAL 2015*; Jackowski, K., Burduk, R., Walkowiak, K., Wozniak, M., Yin, H., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 541–550.
102. Sariyer, G.; Taşkın, D. Clustering of Firms Based on Environmental, Social, and Governance Ratings: Evidence from BIST Sustainability Index. *Borsa Istanb. Rev.* **2022**, *22*, S180–S188. [CrossRef]
103. Kishan, E.; Kiran, V.U. Sustainable Development Goal-8 for Stock Exchanges: An Evidence-Based Performance Analysis of Indian SME Stock Indices. *IUP J. Account. Res. Audit Pract.* **2022**, *21*, 50–86.
104. Koralun-Bereźnicka, J. Multivariate Comparative Analysis of Stock Exchanges: The European Perspective. In *Advances in Data Analysis, Data Handling and Business Intelligence*; Fink, A., Lausen, B., Seidel, W., Ultsch, A., Eds.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 461–469.
105. Acs, Z.J.; Szerb, L.; Song, A.K.; Komlosi, E.; Lafuente, E. *The Digital Platform Economy Index 2020*; SpringerBriefs in Economics; Springer International Publishing: Cham, Germany, 2022; ISBN 978-3-030-89650-8.

106. Acs, Z.J. The Digital Platform Economy and the Entrepreneurial State: A European Dilemma. In *Questioning the Entrepreneurial State: Status-Quo, Pitfalls, and the Need for Credible Innovation Policy*; Wennberg, K., Sandström, C., Eds.; International Studies in Entrepreneurship; Springer International Publishing: Cham, Germany, 2022; pp. 317–344; ISBN 978-3-030-94273-1.
107. Levine, R.; Zervos, S. Stock Markets, Banks, and Economic Growth. *Am. Econ. Rev.* **1998**, *88*, 537–558.

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Do Social Aspects Affect Built-in Car Navigation Habits? A Stereotype Study

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Abstract: We encounter prejudices and stereotypes in all areas of life, including human navigation. This study seeks to answer whether there is a basis for navigation stereotypes such as: does our age, gender, place of residence or country affect our car navigation habits? An online questionnaire was distributed in three Central European countries (Hungary, Romania and Austria) and 1556 respondents were reached. In addition to habitancy (settlement type), it was noted that half of the examined concerns are influenced by stereotypes. A significant difference can be shown in questions that are directly or indirectly related to the financial situation of the driver (e.g., the existence and quality of the built-in GPS depends on whether someone has enough money to buy it). However, it seems that other stereotypes we have about driving and navigation are mostly false. The results suggest that it may be possible to personalize built-in navigation systems. By incorporating various "extra" services (e.g., personalized interface, placement), driving and navigation can be made safer and more comfortable for particular segments of society—the driver does not need to use other devices.

Keywords: navigation habits; car navigation; built-in GPS; stereotypes; statistical test

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1. Introduction

Stereotypes are part of our lives, permeating our everyday life and influencing our actions [1]. They are most often linked to prejudices based on race, religion, gender, sexual orientation, nationality and almost any other social category [2]. Stereotypes can be positive as well as negative. Prejudices with negative connotations still prevail in our society [3]. We often judge others through stereotypes before we are aware of that person's abilities and knowledge. Driving and navigation are activities that are not without prejudice either. Research on stereotypes concerning navigation has examined specific groups such as being over 65 years of age or of a certain nationality. Since safety is a cardinal issue in driving, this research mainly examined aspects of health and safety. Demographic and social class groups were not analyzed.

By accepting stereotypes, we can get to know ourselves (and our environment) better, and thus we can learn and improve certain forms of behavior (e.g., [1,4]). This research has the same goal: to examine the extent to which navigation-related prejudices are based on reality. Based on navigation habits, changes in car navigation can be personalized by both car manufacturers and navigation software companies. If there are significant differences, these recommendations may be even more important. For the elderly, these changes can make driving easier and safer. If there are no differences between drivers, there should be

no basis for stereotypes and they should be avoided. The present research differs from the previous studies (see Section 1.1) in that (1) it examines the use of the built-in GPS in the car; (2) the respondents did not go through any pre-screening; and (3) we did not examine a specific group (e.g., above 65 years or people with some injuries).

The study deals with navigation habits and stereotypes as an unconscious factor in our perception. For this, it was essential to ask some driving-related questions. No series of questions can provide a comprehensive picture of entire driving habits.

The following hypotheses were formulated before the research:

Hypothesis 1: *Stereotypes about car navigation (and driving) have a basis.*

Hypothesis 2: *As we age, our driving habits get worse, and this can be detected. So, (1) we assume that due to the deterioration of health, the elderly drive less and demand more safety, and (2) they do not use electronic navigation aids as regularly as young people, because they do not know how to use them.*

Hypothesis 3: *There is a demonstrable difference in the driving habits of women (bad drivers) and men (good drivers). The general opinion is that women drive less (more in the city) and less confidently and use electronic devices less.*

Hypothesis 4: *People who grow up in different living environments have different driving/navigation habits. Differences due to different financial and cultural backgrounds can be detected.*

This paper first examines previous research and the aspects of creating a useful questionnaire. Then, the completed questionnaire is introduced and the results are statistically analyzed.

1.1. Literature Background

1.1.1. Vehicle Driving and Navigation Habits

The driving habits of car drivers have been examined by several research studies, mainly from the point of view of health and the corresponding risk factors. It was shown that a shorter amount of sleep and younger age of the driver are associated with increased traffic exposure [5]. Auriault et al. studied how the driving habits of pregnant women change as pregnancy progresses: while initially they drive themselves, in the last month they tend to travel as passengers. Regardless of pregnancy stage, almost all women used seat belts and did not make other seat adjustments [6].

It has been shown that more people are driving who should not for health reasons (e.g., glaucoma patients). It was also found that these patients are consciously avoiding (self-regulating) their driving habits to avoid potentially dangerous driving situations [7]. The same pattern was found in drivers wearing a cast (Irish)—15% of orthopaedic trauma patients wore a forearm or below knee cast while driving [8]. According to Shakerinia and Mohammadpoor, drivers should undergo regular psychological check-ups, because certain psychological characteristics (mental health, aggression) are significantly linked to driving behavior [9].

Since driving is so complex (with the combination of physical and mental tasks), most of these are about the driving habits and possible health problems of the elderly, or alcohol influence [10,11]. Some research aims to identify clinical signs that may predict driving difficulties in older people [12] so healthcare providers can personalize messages to support safe driving and patient safety [13]. Bishu et al. examined the needs of the elderly—e.g., increasing the size of traffic signs and parking spaces, lowering speed limits [14]. It has been shown that in older age, drivers pay a lot of attention to driving more carefully—they reduce their daily driving load, and avoid driving at night and during rush hour [15]. They have also been the subject of studies to test drivers with certain diseases. The most common

'handicap' is eye damage. It has been shown that people with vision loss are particularly careful when driving because they are aware of their own limitations [16,17].

A few studies can be found in which gender comparisons were made. It was found that although women drive less on a daily basis (they give up driving more easily than men in adverse circumstances), there is no difference in driving rates overall [18]. Women tend to be more prone to self-regulation and adaptation [19,20]. On the other hand, general comparative studies have not yet been carried out either according to the criteria listed above, or by place of residence.

Several research studies have examined in-car navigation. Similar to our survey, a questionnaire was developed in 2011 by a Hungarian-founded navigation software company, the NNG (developer of iGO Navigation Engine) [21]. According to this, users require an online, constantly updated database, and more complex interaction with the interface. Finally, in this research, the need for a more complex, broader study is also expressed. Based on an investigation on TomTom systems, young GPS users had a more positive experience and association with GPS systems as compared to the elderly [22]. With the development of technology, and as mobile phones became more and more commonplace, applications optimized for mobile phones appeared [23–25].

1.1.2. Stereotypes in Driving and Navigation

There are several ways to define a stereotype [26,27]: the standard point of view is that stereotypes are beliefs about the characteristics, qualities and behavior of members of certain groups [28]. The Oxford English Dictionary defines it as a "widely held but fixed and oversimplified image or idea of a particular type of person or thing". They appear as a way of simplifying the demands made on the perceiver: they facilitate information processing by allowing the perceiver to rely on previously stored knowledge instead of incoming information [3,28,29].

Age and gender stereotypes are the most common areas of research. It has been stated that stereotypes related to elders are multidimensional [30]: both negative and positive driving behaviors are part of the behavioral repertoire. According to Joanisse et al. (2012), the interviewees tended to define someone as elderly even if they did not behave in a safe manner, but also if they showed appropriate and safe types of behavior [31]. It was further shown that the very existence of stereotypes can influence driving habits [32]—positive (considered) and negative (inflexible) age stereotypes can be automatically activated and influence behavior at an unconscious level [33].

The same was shown in relation to gender stereotypes: sex stereotypes associated with driving (SSAD) may influence driving behaviors [34,35]. Some of the relevant research examines the issue from the point of view of safe driving, with fewer accidents being more feminine qualities [36,37]. Since men drive more often, it is still seen as a privilege of men [38]. Women are often considered incompetent at driving, even by women themselves [39]. Overall, it can be said that in all cases, a statistical difference between men's and women's driving habits was shown in the cases where risk avoidance/security was examined.

2. Materials and Methods

2.1. Questionnaires

One of the most common methods of primary data collection in the social sciences is questionnaire interviewing. As we have seen in previous research, they are used with preference in this research topic as well. As we indicated in the introduction, our questions can be divided into two parts. On the one hand, we wanted to gain general knowledge about driving habits (without any other influencing factors), and on the other hand, we wanted to map out the habits related to the use of built-in GPS. While we have a significant amount of research on the former, there are fewer studies in the case of the latter, so we were not able to draw much inspiration when formulating GPS-related questions.

Comparing the questions asked in previous research related to driving habits with those presented in this article, several similarities can be found. Driving in different situations, kilometers traveled, and GPS use in a general sense have already been examined, e.g., in the case of elderly people or settlement type. We also asked these questions in our own questionnaire, combined with the built-in GPS.

2.1.1. Characteristics of a Useful Questionnaire

The way the questions are asked can determine the order, structure, and their wording. Questionnaire queries via the Internet are classified as assisted questions, as the programming allows us to warn the respondent of incorrect answers and lack of answers, and automatically follows the logical connections and jumps between the questions. The downside is that those without the internet are excluded from the study.

Quantitative and qualitative data can be used in a questionnaire [40,41]. Quantitative data describe the quantitative values of the measured variable, and the qualitative data describe the type of observations to which we assign numerical integer values. Four different levels of measurement can be used to describe the data, depending on the content of the values obtained from the measurement and observation. The measurement levels affect the study design and data collection, have a decisive influence on the course of the study, and the statistical methods are also scale-dependent. Examples that are also included in the questionnaire included: gender, marital status or citizenship are nominal data; settlement type is an ordinal type; predefined age groups can be measured in an interval scale; and the number of years spent driving is a scale of proportions [42].

The aim of the questionnaire is to gather as much data as possible from clearly defined, factual data. For a good questionnaire, simple, clear, easy-to-understand questions must be formulated, to which we can expect clear, preferably quantifiable answers [43,44]. In general, it can be said that it is important to keep the questions as short as possible [45–47]. Several researchers note that it is worth getting the ideal number of words in a sentence between 16–64 words [48,49] and keeping the grammatical complexities to a minimum [46,48,50], so the respondents' mental capacity is freed up to think about the answers [51]. It is definitely advised to try out the questions on a relatively small sample to determine that it does not require too much effort for the respondents [52,53].

2.1.2. Structure of Our Survey

Following the guidelines for questionnaire design, the survey was designed to reach as many people as possible. The same questions were asked in order to make the results comparable between different aspects (see Section 2.2). The questions were translated into the different languages to capture the same meaning of each question. Google Forms was used because most people are familiar with this online platform. The questionnaire was distributed in the three countries. It was first made available in Hungary (since the first author is Hungarian) for two months (from December 2018 to February 2019), then in Romania for four months (from September 2019 to December 2019), and finally in Austria for three months (from September 2020 to November 2020).

In each case, snowball sampling was used [54]. It is one of the most popular sampling methods in qualitative research. It starts with a small number of contacts, who are invited (and fit perfectly) to the research. Then they are asked to recommend other contacts who fit the criteria, etc. Sampling usually finishes if the target sample size has been reached. There are disadvantages of this method: it may be viewed negatively for not preparing random samples in a statistical sense, and the basis for establishing the representativeness of the samples can also be questioned [55]. For this reason, the answers in our research cannot be considered representative.

By country, the least number of responses came from Austria. By age group, the least came from the older population. While most elderly use the Internet, the questionnaire was not as easy to access for them. That is why in some cases the link (see above) was sent on paper/e-mail.

Figure 1 shows the structure of the questionnaire. The 50 questions asked can be found in several languages (Hungarian, Romanian, German and English) at https://mercator.elte.hu/~vorosfanni/navigation.html (accessed on 25 February 2023).

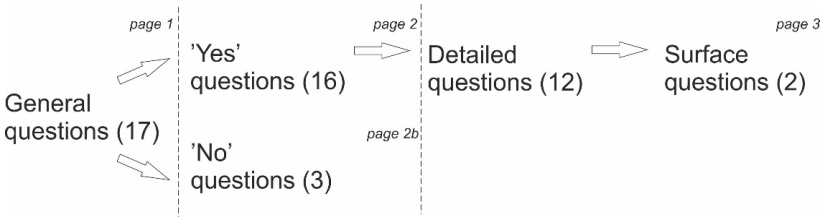


Figure 1. Structure of the questionnaire and the number of asked questions in brackets.

On *page 1* (after a short description of the interviewer and the research), 17 questions were asked. The first few questions were demographic (objective data with pre-defined possible answers) and introductory (multiple choice and intensity issue). Depending on the answer to the last question, other questions followed.

On *page 2b*, three open-ended questions were asked, which respondents could answer at any length. We also provided pre-defined answers as guidance. *Page 2* and *3* contains information about built-in navigation-system usage habits. As the questionnaire was relatively long, in most cases we asked closed questions and gave a choice of pre-defined answers. On *page 3*, only two questions were asked about the current and the needed GPS surface. The questions related to driving habits. There are several issues that, although about the navigation system, are related to driving habits and have been processed. Examined questions and numbers of answers can be seen in Table 1.

Table 1. Examined questions and the number of respondents. The first seven questions were obligatory for everyone, the rest only for those who have built-in navigation system in their car.

Question	Answers
Your (or your most commonly used) car's age?	1556
Did you buy a used car?	1556
How often do you drive in these situations?	1556
On average, how many kilometers do you drive per year?	1556
If you had no financial limit, would you use a self-driving car on a daily basis?	1556
Do you have built-in GPS in your car?	1556
Do you use your built-in GPS?	1556
How often do you use the built-in GPS in these situations?	213
Where do you usually plan your trip?	213
Do you update your built-in GPS?	213
How often do you update?	213
In addition to the built-in GPS, what other navigations do you use in these situations?	213
Where would you place the navigation information (e.g., arrow) in your area?	213
Do you turn off the "night mode"?	213
If the built-in navigation system offers alternative routes when planning a route, do you watch it?	213
Do you specify intermediate (more) destinations (e.g., gas station, restaurant)?	213
What addresses do you save to your favorites?	213
If so, how many addresses do you save?	213
Do you use the GPS interface while driving?	213
If you use the interface on the go, when exactly?	213
If you use the interface while driving, for what reason?	213

2.2. Comparative Aspects

Stereotypes are most often based on gender differences and social status (e.g., place of residence). In addition, with a smaller negative tone, but in the same quantity, we can

find comments related to age. The first few (mandatory) questions of our questionnaire asked for general, demographic data. In this publication, the answers have been grouped according to these aspects: age, gender, habitancy and country. The created groups can be seen in Table 2. These comparative aspects were later subjected to a statistical test: the Pearson Chi-square test.

Table 2. Overview of the comparative aspects and the created groups.

Age	Gender	Inhabitancy	Habitat
under 25	male	village	Hungary
25–35	female	city	Romania
36–45		county seat	Austria
46–55		capital	
56–65			
above 65			

3. Results

The 21 questions asked (Table 1) were examined according to the 4 criteria presented above (Table 2). Since we examined different stereotypes, it is advisable to group the results according to them.

3.1. Results Based on Age Groups

Hypothesis 2: *As we age, our driving habits get worse, and this can be detected. So, (1) we assume that due to the deterioration of health, the elderly drive less and demand more safety, and (2) they do not use electronic navigation aids as regularly as young people, because they do not know how to use them.*

As it was mentioned above, six age ranges were defined: under 25 years, 25–35 years, 36–45 years, 46–55 years, 56–65 years and above 65 years. The age of the cars varies as follows depending on the age of users: 17.3 -> 15.6 -> 14 -> 13 -> 14.3 -> 14.5. Based on this, the youngest age group sits in the oldest cars, while the 46–55 age group sits in the youngest cars. In Figure 2, an overview of eight different driving situations can be seen: from everyday trips to foreign trips. The pre-defined different driving situations can be seen in Table 3.

Table 3. The pre-defined driving environments and their matched serial numbers.

Situation	Driving Environment
1	Everyday routes within the city (e.g., workplace)
2	Everyday routes between cities (e.g., commuting to work)
3	Other routes within the city
4	Other routes between cities
5	Weekend trips
6	Domestic holidays
7	Holidays abroad
8	Other abroad trips

The following can be observed: (1) Most often they drive in “other routes within and between the cities”, “weekend trips” and “domestic holidays”; (2) In the other four cases, the “never” answer occurs much more often. For everyday travels, they likely use public transport (although there are also the most “always” answers on routes within the city), while long-distance travel is less frequent; (3) In cases (a–d), the oldest age group drives the least often; and (4) Although no major differences can be observed beyond these, in general, the 36–45 age group drives the most.

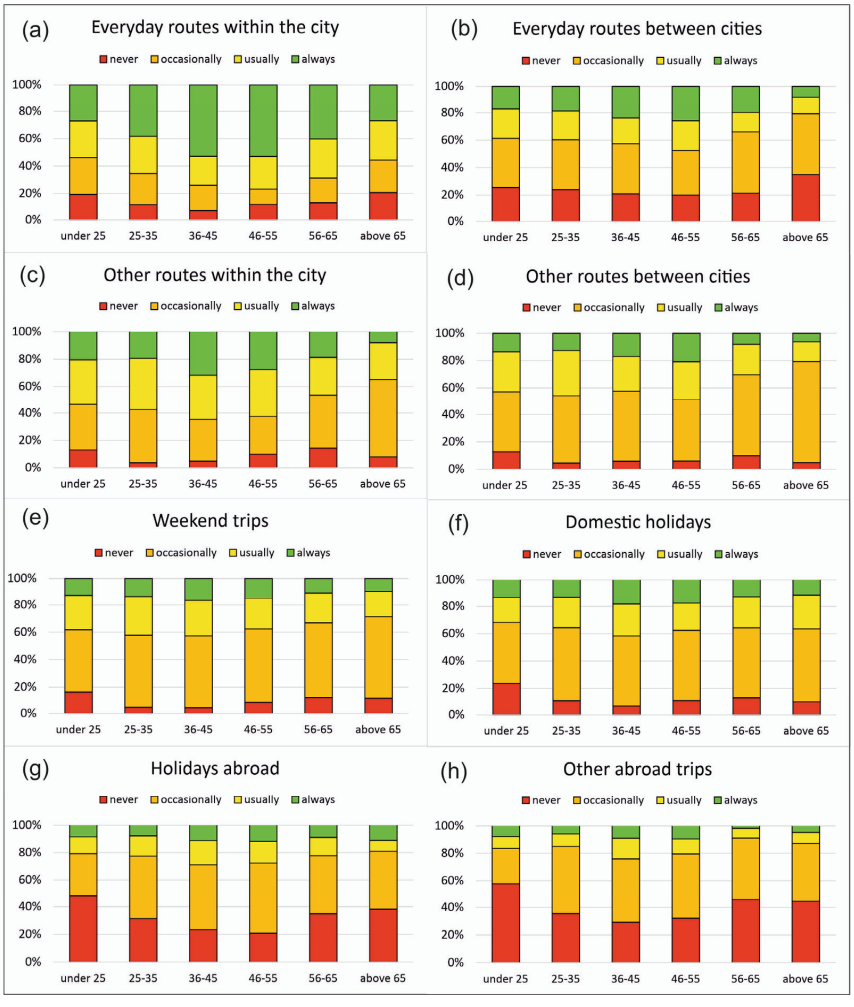


Figure 2. Driving frequencies by age groups in different driving environments.

Figure 3 depicts ownership and average driven kilometers/year. There is a clear trend towards the former: the older someone is, the more likely they are to drive their own car. There is only a slight decline in the oldest age group: the proportion of used cars is increasing. On the other hand, they practically do not use anybody else's car—these two can mean they buy their children's/grandchildren's car. As expected after Figure 2, the 36–55 age group leads the most in each year. More than 80% of the oldest age group drive more than 5000 km a year. Young people drive the least, presumably using public transport more often. As we can see in Figure 2, they also travel abroad the least.

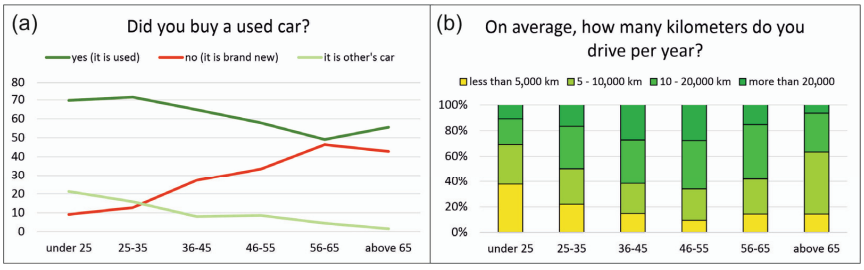


Figure 3. (**a**) ownership of the cars and (**b**) average driven kilometers/year—grouped by age.

We asked if drivers would use an autonomous car if there were no financial constraints. Except for the 65+ age group (where it has just reached 20% support) in 60–40 ratio, "no" won. Interestingly, the older someone is, the more likely they are to have and use built-in navigation. However, even in this age group, built-in navigation remains at only 20%.

The last two questions in the common part were whether the driver has a built-in GPS and uses it. As noted, there is a correlation between the age of drivers and the presence and use of built-in GPS: the older someone is, the more likely they are to use the device (Table 4). The third column shows what percentage of those with GPS use the device.

Table 4. Percentage of users with built-in GPS by age groups.

Age	Has Built-in GPS (Percentage | Number)	Uses the GPS (Percentage | Number)
under 25	16% | 58	57% | 33
25–35	18% | 87	52% | 46
36–45	25% | 79	61% | 48
46–55	24% | 54	74% | 40
56–65	27% | 30	97% | 29
above 65	29% | 17	94% | 17

The other questions were answered by fewer people (213) as they are connected to the built-in navigation system in some way. In Figure 4, built-in usage frequency can be seen in different driving situations. It can be seen that GPS is used least often on everyday routes, presumably because these are daily roads, and most people know the route by heart. It is also used less on foreign roads. Examining this figure together with Figure 2, it can be seen that the youngest go the least on holiday/abroad (so that they drive), so it is understandable that they use GPS less.

Depending on the above-mentioned driving situations, we asked where and when respondents are planning their journey. The options were "I don't plan it", "before departure" and "in the car just before leaving". As expected, in options (a,b) (everyday routes) non-planning dominated. In (c,d) mainly the "in the car" possibility has been selected—the extent of non-planning is declining. From (e–g) practically every age group plans their journey even earlier, before they leave and not in the car. Groups 36–55 were more likely to plan just before departure. In the context of the results presented so far (Figures 2 and 4), in the case of "other abroad trips", in many instances they do not plan their journeys—as they do not have those. There are some correlations between planning and ages: in an everyday, "near" environment, both young and old are more likely to plan ahead. It is also the middle-aged classes [36–55] that plan their trips just before departure. The youngest are more likely to plan well in advance.

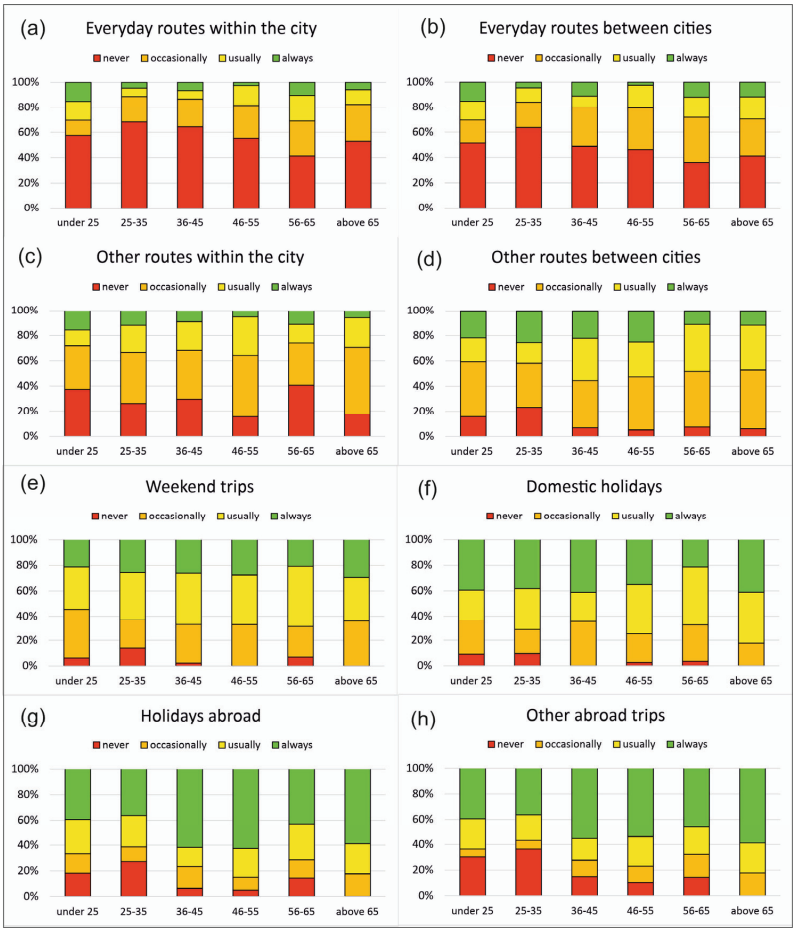


Figure 4. How often do you use the built-in GPS in different situations?

In more than half of the cases (in some cases, more than 3/4), drivers update their databases in the navigation units. For the most part, the older someone is, the more likely they are to deal with an older database. For each age group, there are several answers that address whether users pay for this service. Regardless, however, the most common reason for not upgrading is the expense. In Figure 5b, it can be seen that even if they pay attention to upgrading their system, half of the respondents do it less than annually.

In the questionnaire, five options for built-in navigation systems were given. The 1st option favors left-handers in particular, as it is easier for them to handle the surface on the left. The 2nd place is behind the wheel on the dashboard. The 3rd option is at the top of the central console. GPS in the central console itself, in its "usual place", is the 4th possible place; while the 5th is when the surface is projected onto the glass. Only a few votes were cast for the first option (Figure 5c). In general, the other four options are equally desirable for drivers. The "usual place" is most coveted by the youngest and oldest groups. Most like the night mode on the display. Everyone, regardless of age, checks the alternative routes offered—the oldest group in every case. Everyone loves the "night mode" feature as they do not turn it off. There is no trend of giving waypoints—the majority do not take this opportunity. The younger generation save fewer addresses to favorites (mostly family members) than the older ones. Based on Figure 5f, it can be said that someone is

more likely to use GPS while driving if they are younger. Forty percent of drivers interact with it when the car is moving—not when they are stopped. As you get older, people are increasingly handing over navigation to someone else. In the vast majority of cases, they use the interface to enter a new address.

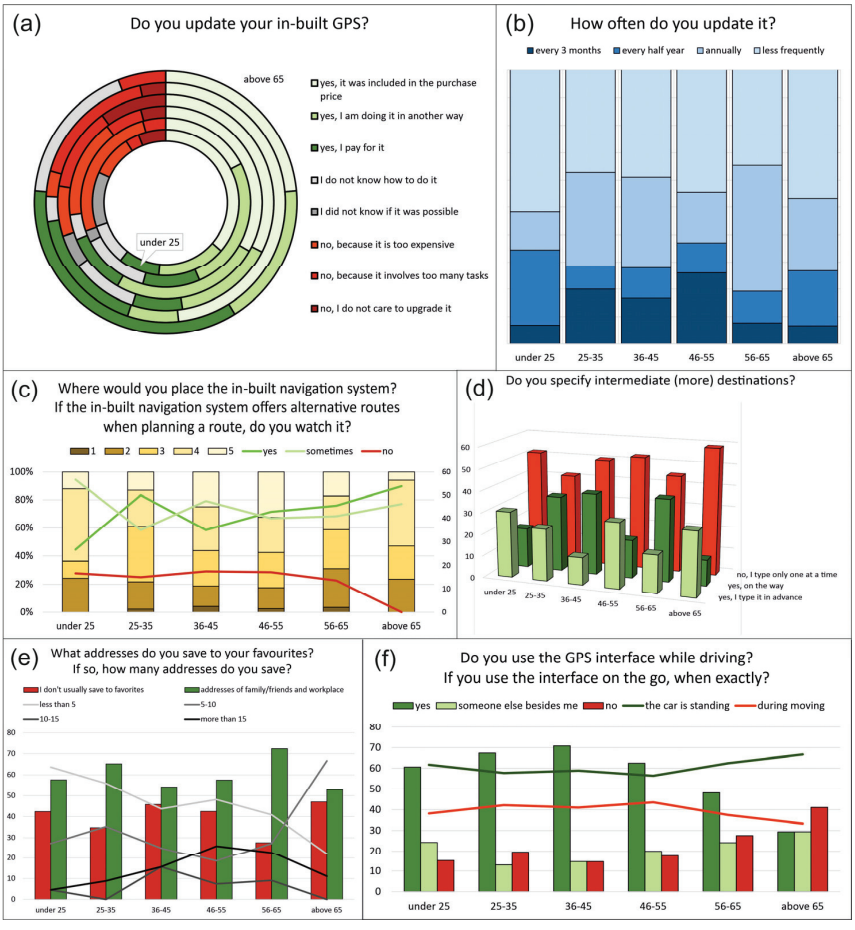


Figure 5. Answers about (**a**,**b**) updating habits, (**c**) placement and alternative routes, (**d**) intermediate destination, (**e**) favorites and (**f**) GPS use while driving.

The surface chart in Figure 6 shows what other additional navigation is used by drivers. The numbers in the *x*-axis represent the driving situations presented in Table 3. Options were given in the questionnaire for what apps and devices can be used in addition to the built-in ones. These can be seen on the *y*-axis. Coloring depends on the ratio (%) of responses to a given situation; these numeric values are specific values at the intersection of situations and application options. The coloring between grids is created by interpolation to give a hypsometry-similar look.

Several correlations can be drawn: (1) the younger age group uses far fewer types of applications than the older ones: Google Maps, Waze, and Apple Maps dominate (but the latter is only for the youngest); (2) older people use paper maps more often, especially for unknown (foreign) roads; and (3) drivers under 35 are much more likely to bring out some aids to navigate.

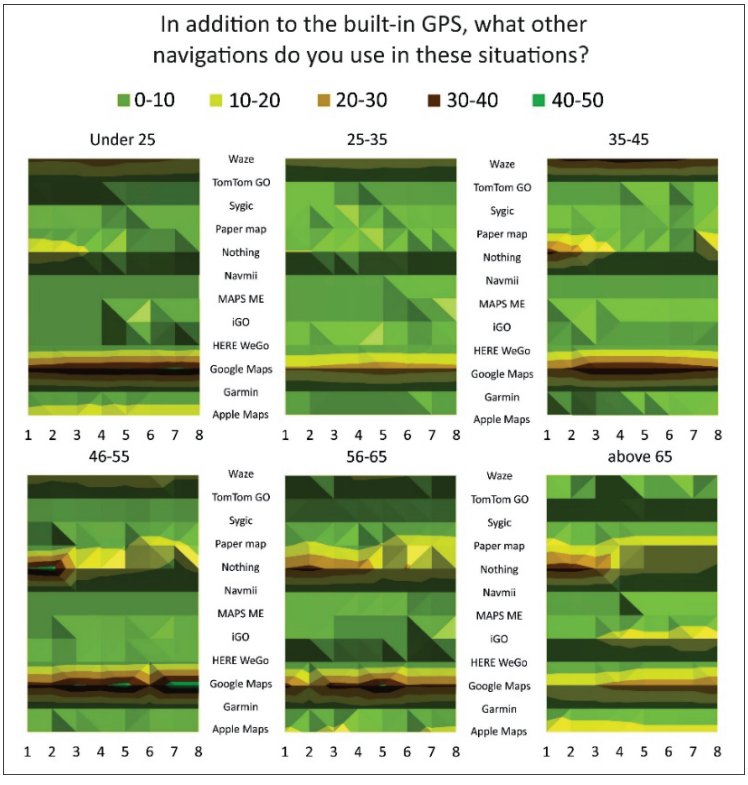


Figure 6. Other navigation devices used in different driving situations—grouped by age groups.

3.2. Results Based on Gender

Hypothesis 3: *There is a demonstrable difference in the driving habits of women (bad drivers) and men (good drivers). This means that, according to our prejudices, women drive less (more in the city) and less confidently and use electronic devices less.*

Results for men are presented, followed by those for women. The average age of men's cars is 14.7 years, while women's are 15.2. In terms of usage, the data are almost identical: 66–63% had used cars, and 21–21% had new cars. In Figure 7a, the declining trend presented earlier is shown: the less "close" a road is, the less often people drive. There is only a few percent difference between the genders; 23–15% have a built-in GPS and about 64% use them. Women use the built-in GPS less often (proportions of "always" and "never" answers in Figure 7b). There is not much difference for everyday trips. The difference is greater for less frequent trips. Figure 7a,b are almost perfect mirror images of each other. It can be seen from this that there is a correlation between the frequency of built-in GPS usage and driving.

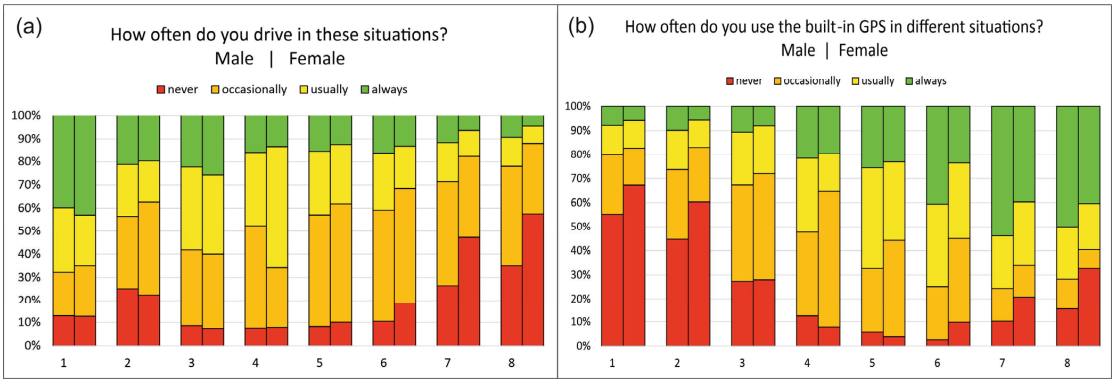


Figure 7. Frequency of (**a**) driving and (**b**) built-in GPS usage in different driving situations—grouped by gender.

The difference in mileage is more striking, as can be seen in Figure 8a. Sixty percent of men drive over 10,000 km/year, compared to 30% of women (usually, when the family goes on vacation together, men prefer to drive). In terms of updating the database, women are less aware of their options and almost a quarter of them do not know how to do it. However, the ratio of non-updates between the two genders is quite similar (both 25%) (Figure 8b). The frequency of updates is almost the same: 30% do it more often than annually.

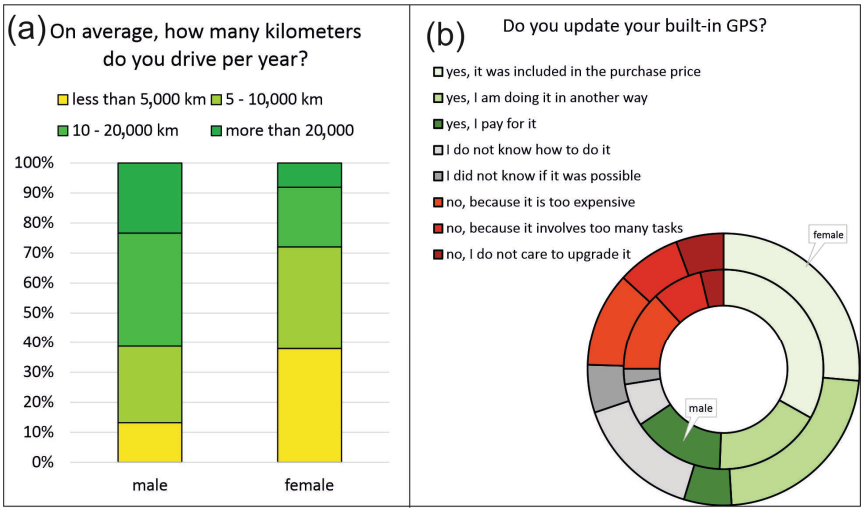


Figure 8. (**a**) The number of annual kilometers driven and (**b**) updating habits—grouped by gender.

We examined by gender if the respondents specify intermediate destinations. More than 60% of women enter only one destination at a time, compared to only 40% of men. Men enter extra destinations while driving twice as many times as women (see Figure 9a). Just over half of the women save addresses to favorites, and 70% of them save less than five. Men do just the opposite.

Figure 9b shall be understood as follows: the results indicated by the green and red lines (answers for the question "If you use the interface on the go, when exactly?") are obtained by examining the two "yes" answers to the first question ("Do you use the GPS interface while driving?").

The above-mentioned contrast also appears when using GPS while driving: almost 70% of men and less than 50% of women use it by themselves on the way (not the passenger). Of those who use it, in almost every second case, men do it when the car is moving. For women, this rate is only 20% (Figure 9b). For both genders, it is mainly used to input a new address.

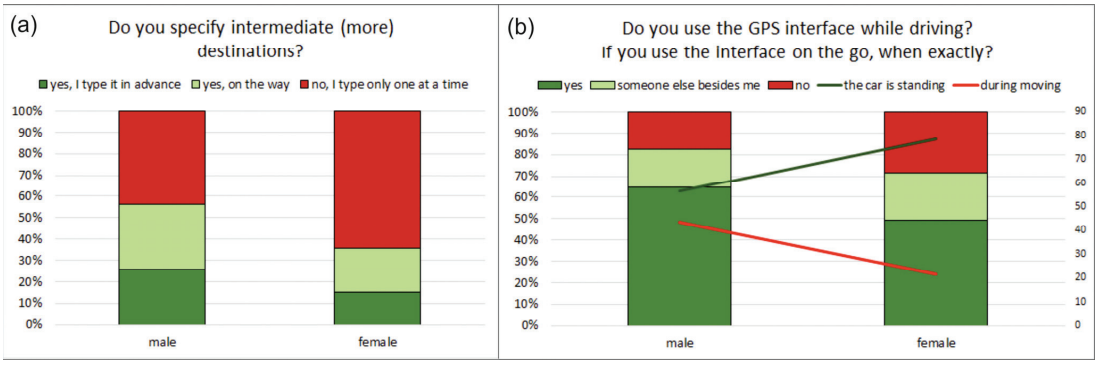


Figure 9. Answers about (**a**) intermediate destinations and (**b**) GPS usage while driving—grouped by gender.

A few differences for other used applications can be detected: (1) men know and use more applications, (2) women drive only on the most daily roads without any help, (3) women mainly use google maps in all situations. Fifty percent of men and 30% of women would drive a self-driving car if they could choose this possibility. There is no significant difference in the location of planning either: on average, women plan their journey 10–12% more times in advance. With the exception of two situations (3,5) men plan their journeys less often. Even in this case (grouping by gender), in addition to the "left-handed" (1) option, the answers are roughly evenly distributed among the other four, where they want to place the built-in GPS. The majority (~80%) do not turn off night mode.

3.3. Results Based on Habitancy Groups

Hypothesis 4: *People who grow up in different environments have different driving/navigation habits. This follows from the different distances, road conditions and environment (whether natural or built).*

Four types of residences could be selected: village, city, county seat and capital; with results presented in this order. In terms of the age of the cars, 15-15.2-15.2-14.2, there is no significant difference. Cars of those living in the capital are one year younger. Moreover, 65–69% of drivers bought used cars, except (again) in the capital where it was only 60%. This difference also appears in the "I use other's car" option, where in the capital almost 20% do so. In the other three scenarios, only 10% marked this answer. There is no significant difference in the number of kilometers driven annually (Figure 10a), or in the existence and use of GPS.

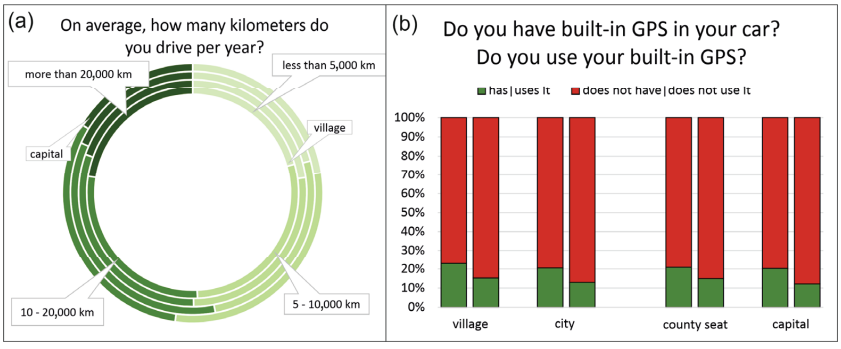


Figure 10. (**a**) The number of annual kilometers driven and (**b**) GPS usage and existence—grouped by inhabitancy.

Figure 11 should be interpreted as follows: the driving situations defined in Table 3 are shown on the *x*-axis (from 1 to 8). The answers ("I do not plan it", "before departure" and "in the car just before leaving") to the question ("Where do you usually plan your trip?") can be seen grouped by place of residence on the *y*-axis. Regarding GPS usage, the proportion of "always" answers increases from 1 to 8 in all cases, while "never" changes as follows: it decreases from 1 to 5 (so weekend trips have the fewest never answers), then increases again. There is a slight difference in the ratio of "usually" and "occasionally" answers—the least common in the capital being "occasionally". Likewise, no significant changes in road planning can be seen in Figure 11a–c. The more distant they travel, the more they tend to plan ahead; earlier, in their living area, not immediately before departure.

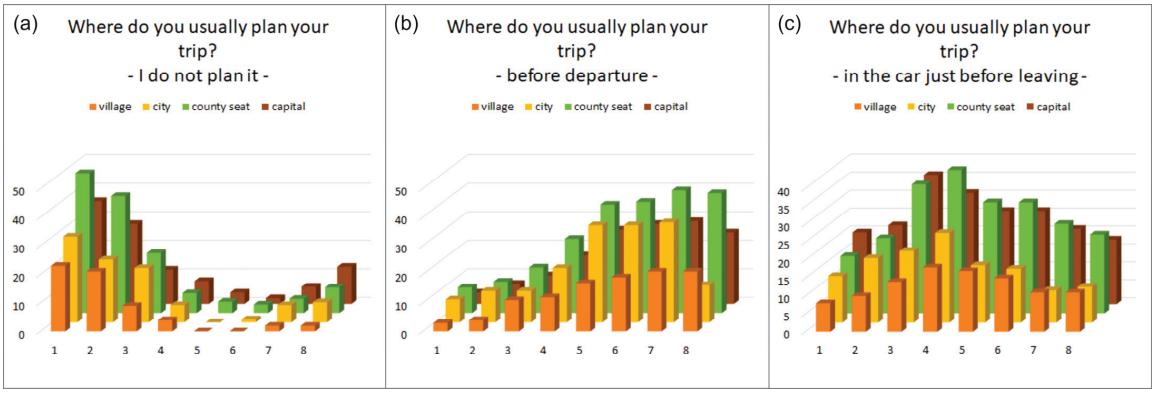


Figure 11. Road planning habits—grouped by inhabitancy and situations.

A small difference can be detected in the update of the built-in navigation: only 50% of the respondents living in the capitals upgrade, while in the other three places this value is closer to 70%. Almost 10% of the residents of the capitals and county seats do not know how to carry out the update. This was not the case in the case of those in villages and towns. Roughly 30% update it more often than once a year—interestingly, this is done least often in villages and capitals.

Regardless of where they live, most people use "Google Maps" for navigation. Waze is used second-most. In the case of villages, approx. 20% use "Apple Maps". A significant difference can be observed in the case of "nothing" and "paper map". In the case of villages and towns, situation 4 is last, while it is present in all driving situations in the county seats

(~20%). In the case of the capital, they are indicated at 1–2 and 6–8, only for (weekend) holidays were they not given as an answer (Figure 12).

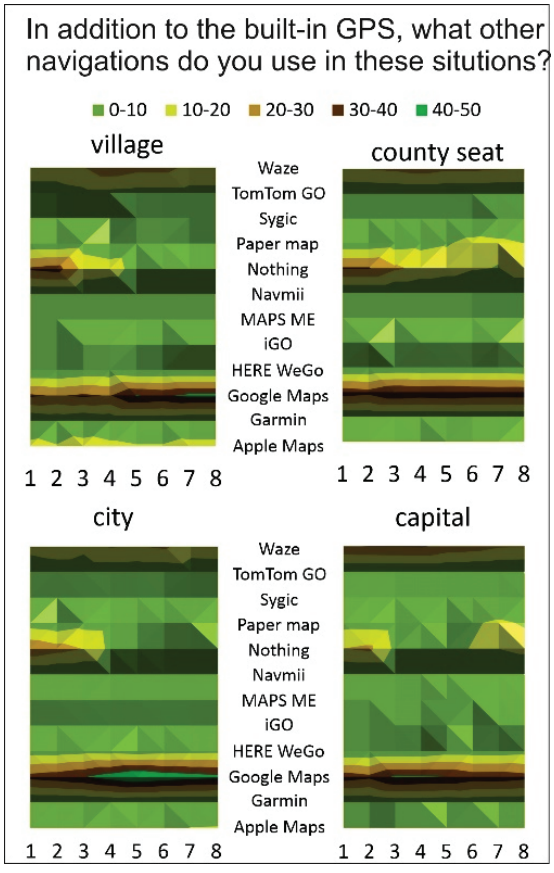


Figure 12. Other navigation devices used in different driving situations—grouped by inhabitancy.

In the case of respondents in capitals, the least number indicated that they would like to see the orientation information projected on the windshield. They would place it at 25–35% in the "current location". The 3rd option (top of the central console) was nominated by only a few people from the city; the other three places of residence all wanted ~25%.

The ratio is exactly the opposite for option 2 (behind the wheel on the dashboard). Alternative routes are looked at least often in county seats. Variability can be found in specifying intermediate targets. The bigger a settlement, the less they think ahead. In villages and county seats, they prefer not to enter more, while in the capital/cities, entering addresses on the way dominates. There is also no correlation in the addresses saved/unsaved in favorites: the largest proportion (70%) of the residents of the capitals use this opportunity: about 50% save less than 5 addresses (Figure 13a). Most people (70%) use the GPS interface while driving in the capital, but the fewest (cities) use it also, at 55%. Both "when" (60% in a standing car) and "for what" (to enter a new address) received the same proportion of answers (Figure 13b).

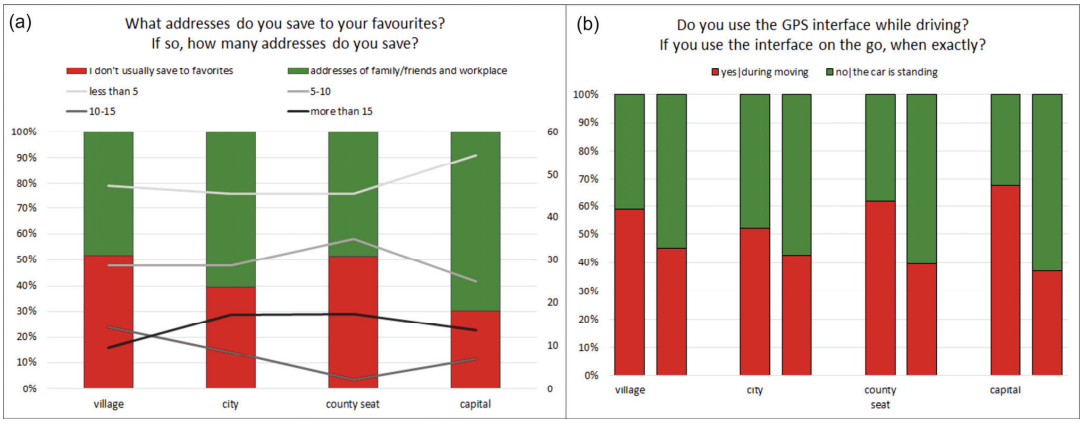


Figure 13. Habits of (**a**) saving to favorites and (**b**) GPS usage while driving—grouped by inhabitancy.

3.4. Results Based on Habitat Groups

Hypothesis 4: *People who grow up in different environments have different driving/navigation habits. Differences due to different financial and cultural backgrounds can be detected here.*

The questionnaire was completed in three countries (in this order): Hungary, Romania and Austria. There is a great difference in the age of used vehicles: while the average age of Hungarian and Romanian cars is ~15 years, the average age of Austrian cars is significantly younger, 10 years (Figure 14a). 65% of Hungarians and 74% of Romanians bought a used car, while only 37% did so in Austria. In contrast, Austrians drive other people's cars at a higher percentage. Hungarians and Romanians drive more often on "everyday" roads, and this proportion decreases along with further distances. While in the case of Austrians, this decrease cannot be seen.

Austrians drive abroad almost as often as they do at home, on a daily basis. Interestingly, however, looking at the average number of kilometers driven per year, it is more common for Austrians to travel less. While in the other two countries, the distances are distributed practically exactly the same (20-30-30-20%); in the case of the Austrians it is: 30-35-30-5%. Austrians would rather use a self-driving car, but even in their case, only half of the respondents answered this.

Significantly fewer Hungarian (18%) and Romanian (22%) cars have built-in GPS (Austrian: 45%). These are also the proportions in their use: Hungarians (10%) use it the least, and Austrians (40%) the most (out of all the people interviewed). If we examine the percentage of drivers who have a device in their car and use it, the situation is better. However, there is a difference here as well: 88% of Austrians and 60–63% of drivers in the other two countries use it (Figure 14b).

GPS usage in certain situations can be seen in Figure 15. The nature of the answers is the same in the three countries: the proportion of "always" answers increases continuously from 1 to 8. The "never" responses decrease until situation 6, and then start to increase again. The difference lies in the proportions: Austrians have fewer "always" answers than the other two countries, and more answer "usually". The same is true for planning the road. "I don't plan" decreases until situation 6, and then starts to increase again; while the opposite is true for planning in the car (immediately before driving): its frequency increases until situation 4, and then decreases. On everyday trips, Hungarians tend not to plan.

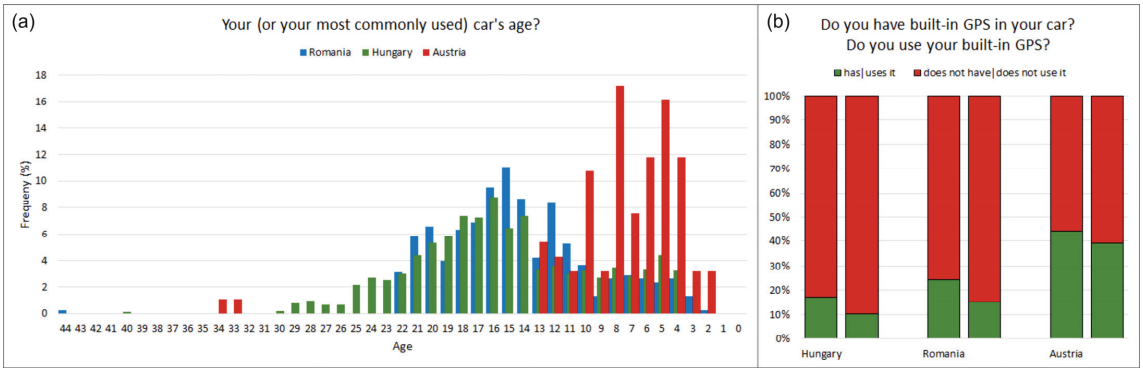


Figure 14. (**a**) Frequency distribution of the cars' age and (**b**) GPS usage and existence—grouped by countries.

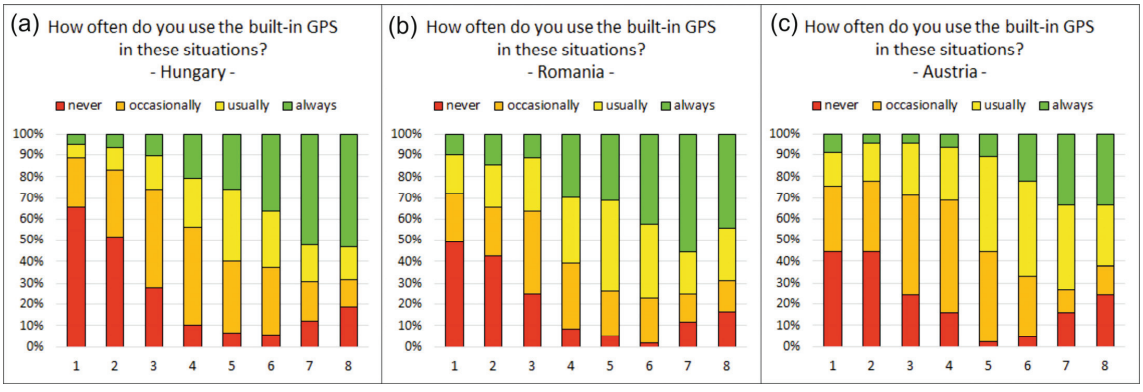


Figure 15. Frequency built-in GPS usage in different driving situations—grouped by countries.

Three quarters of Romanians, 60% of Hungarians, and only half of Austrians update their GPS database. Austrians most commonly answered that they do not know how to update. The most common reason for not updating is that it is too complicated. None of the Romanians indicated this reason. In connection with this, 30% of Romanians update it every 3 months—in a similar proportion, only 30% do it less often than a year. Austrians perform the worst: approx. 5% do it every 3 months, while more than 60% update it less often than one year.

Significant differences can be observed in what applications/devices drivers use (Figure 16). The Hungarians show the most diverse picture: regardless of the driving situation; Google Maps is used most often, closely followed by Waze. What is interesting is that both the "paper map" and "nothing else" appear in a significant percentage of all cases—especially often for everyday ("nothing else") and foreign trips ("paper map"). The same is typical for Romanians: Google Maps and Waze are used in 40–50% of cases, but "nothing else" and "paper map" are typical only in the first three situations. They use something for navigation in all the other cases. The most homogeneous answers came from the Austrians: Google Maps dominates unanimously (60%), and in addition to "nothing else", only Apple Maps received a significant number of votes.

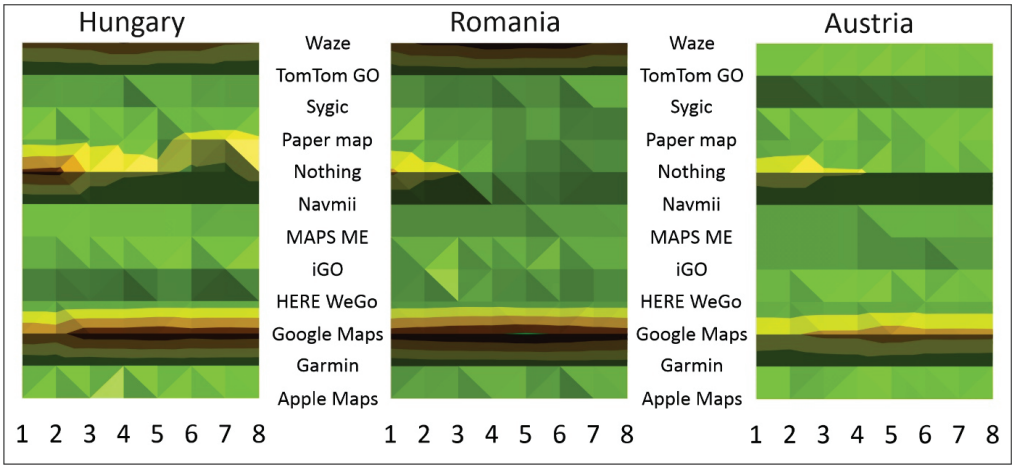


Figure 16. Other navigation devices used in different driving situations—grouped by countries.

Hungarians do not clearly know where they want the built-in navigation interface—the answers are split 25–25% (except for the left-handed option). In the case of Romanians, it can already be seen that the fold-out and the current placement are the favorites. The situation is the clearest with the Austrians: almost half of the respondents are satisfied with the current placement.

Concerning the night function, a very small percentage of drivers disable this function; 84% (Hun, Au) and 92% (Ro) like and use it. Romanians look at alternative routes most often—50% always, 30% occasionally. In the case of the other two countries, the results are just the opposite. The drivers of all three countries prefer to enter one point in the device at the same time—in the case of the Austrians, the "type it in advance" also appears in a significant percentage. In their case, the fewest addresses are saved to favorites: 70% save less than 5. It's the opposite for the Hungarians, in their case the most common is to save several (up to 10) addresses.

Whether drivers use GPS while driving makes no difference: 60% do so in all three countries. Unfortunately, almost 40% do this when the car is moving—the Romanians are the most careful with only 30% doing so, while 40% prefer to stop when touching the surface.

4. Discussion

Stereotypes are based on placing one (or several) groups above or below others in a given topic—that is, comparison (usually without any scientific aspects). We did the same through the results presented above. Following the previous research, the obtained results were also tested with a statistical test.

The Pearson Chi-square (χ^2) test is a statistical procedure for examining variables with (or can be converted to) discrete distributions. Nominal (or categorical) variables are considered discrete variables. There are different categorical variables, the basic expectation is that an entity (person, thing, etc.) can only fall into one category (the most common example of this type of variable is gender). But it is also a categorical variable whether someone answered the question correctly or not, and who among the potential candidates they voted for in the end. It is important to note that variables with a continuous distribution can also be made discrete by forming a finite number of categories (for example, age categories, etc.). In the case of discrete variables, the frequency of which elements/variables fall into each category can be analyzed. Relationship analysis is worth doing if we are wondering whether there is a correlation between what an individual assumes within two categorical variables—do the expected frequencies in each category differ in a random level?

We first examine whether having a built-in GPS is related to the age of drivers. In this case, the null hypothesis is that possession is independent of age. If $p > 0.05$ then the null hypothesis is rejected. In Table 3 the p values are presented for every question. It is important to note that we are only showing whether there is a correlation—and between which groups, etc. For $p = 0.05$, depicted with red numbers, we can say that there is some correlation. In cases where there were several possible answers, the results have been aggregated.

We now examine whether the stereotypes that we (and previous research) have described are supported by our results:

We assume that the older someone is, the slower and safer they drive, as they are aware of their own limitations (see previous research), and they are not aware of newer technological tools (or even if they are, they don't use them that often). Examining the first column of Table 5 (and the Results section), it can be seen that this is only partially true. They are more thoughtful (e.g., planning habits), drive less and pay more attention to safety (e.g., they don't use the built-in GPS while driving), which supports what was found by others [15–17]. Surprisingly, they know and use the device anyway. Based on these results, it seems that their GPS usage habits are the same as those of younger people.

Table 5. Results of the Pearson Chi-square test. Significant differences ($p < 0.05$) in bold.

Question	Age	Gender	Inhabitancy	Habitat
Did you buy a used car?	**<0.001**	0.4	**<0.001**	**<0.001**
On average, how many kilometers do you drive per year?	**<0.001**	**<0.001**	0.59	**0.006**
If you had no financial limit, would you use a self-driving car on a daily basis?	**0.02**	**<0.001**	0.32	**0.03**
Do you have built-in GPS in your car?	**0.03**	**0.001**	0.87	**<0.001**
Do you use your built-in GPS?	**<0.001**	**0.001**	0.5	**<0.001**
Where do you usually plan your trip?	**0.04**	0.1	0.96	**<0.001**
Do you update your built-in GPS?	0.3	0.15	0.18	**0.01**
How often do you update?	0.2	0.7	0.36	**<0.001**
Where would you place the navigation information (e.g., arrow) in your area?	0.2	0.4	0.3	0.1
Do you turn off the "night mode"?	**0.04**	0.18	0.7	0.53
If the built-in navigation system offers alternative routes when planning a route, do you watch it?	0.65	0.99	0.2	0.18
Do you specify intermediate (more) destinations (e.g., gas station, restaurant)?	0.8	**0.01**	0.05	0.58
What addresses do you save to your favorites?	0.6	0.07	0.08	0.5
If so, how many addresses do you save?	0.1	0.1	0.8	0.05
Do you use the GPS interface while driving?	**0.03**	**0.04**	0.4	0.99
If you use the interface on the go, when exactly?	0.98	*0.01*	0.87	0.34

The most common stereotype is that women cannot drive, and that the act itself is considered a male occupation. In other research, we have seen that women tend to pay more attention to safety and drive more carefully, as found in [36,37]. That is why they give up driving first if they deem the situation tiring/dangerous. Longer trips are preferred to be handed over to male members of the family. The other prejudice is that women are not as friendly with electronic devices. Based on the research, these stereotypes all prove to be true. However, women who have GPS use it with the same confidence as men.

When examining respondents living in different types of settlements, we might expect different driving habits. Based on the results, no differences were found.

Wherever we live in the world, we probably all have our own preconceived notions about the countries (and inhabitants) around our own country. The authors of this article are no exception—they had their own prejudices in relation to the three countries examined. Some of these turned out to be true: examining the last column of Table 5, it can be said that the western country with a higher GDP (Austria) is clearly separated from the other

two in half of the examined questions. In the other half, however, there is no difference: if we look at those who use built-in GPS, there is no difference in usage habits from this point of view. After examining the answers to the questionnaire grouped by age, gender, place of residence and habitat, the following can be said:

Hypothesis 1: *Stereotypes about car navigation (and driving) have a basis.*

Any driving or navigation habits are independent of habitancy. In the case of the other three aspects, a significant difference can be shown in half of the 16 examined questions. In general, most of these connected to the drivers' earnings/financial background. Based on this, it cannot be said that there is a clear connection between certain social characteristics and driving habits.

Hypothesis 2: *As we age, our driving habits get worse, and this can be detected. So, (1) we assume that due to the deterioration of health, the elderly drive less and demand more safety, and (2) they do not use electronic navigation aids as regularly as young people, because they do not know how to use them.*

A difference can be shown in the (non)planning, "night mode" usage and the usage of the GPS while driving. A closer look reveals that the older age group prefers to plan ahead and does not use the device while driving—which shows that they are more thoughtful and pay more attention to safety.

Hypothesis 3: *There is a demonstrable difference in the driving habits of women (bad drivers) and men (good drivers). The general opinion is, women drive less (more in the city) and less confidently and use electronic devices less.*

There is a difference between giving multiple addresses (women do not do it) and using the interface while driving: men use it more, while women prefer not to do it, or if they do, only when the vehicle is stationary (e.g., at a red light). On the one hand, this shows the thoughtfulness of women, and on the other hand, that they prefer to avoid more complex tasks.

Hypothesis 4: *People who grow up in different living environments have different driving/navigation habits. Differences due to different financial and cultural backgrounds can be detected.*

Any driving or navigation habits are independent of inhabitancy; in the examined three countries (see more in [56]), there are differences in planning and updating habits, although the latter may also be related to earnings.

5. Conclusions

Because stereotypes can influence how we behave, it is important to examine their legitimacy. It seems that the stereotypes we have on driving and navigation are mostly false. If the drivers have similar backgrounds, there will be no differences in their habits, even if we assume that women or older people do not understand the devices. Although, in this article, we only examined navigation and closely related driving habits, based on the fact that no clear differences can be shown in most comparisons, we can assume that there will be no significant differences in other driving habits either (e.g., in the male-female relationship). Based on the issues examined here, it would be worthwhile to examine this with comprehensive research in the future—not using an online questionnaire, but, e.g., testing with eye tracking.

The following limits can be stated during the questionnaire: (1) due to the fact that the questionnaire was online, it was more difficult to reach the older age group (it required a different form of distribution), so we were able to achieve fewer completions. (2) Since the distribution of the questionnaire began in a university environment, the age group

thus reached was also a difficulty. (3) Due to the same reason, the number of fillings in the capital was also in the majority. In summary, we warn against using unfounded stereotypes as examples because it seems (with one or two exceptions that have their own social reasons) that most driving and navigation differences depend not on the social but on the material background.

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References

1. Carter, J.D.; Hall, J.A.; Carney, D.R.; Rosip, J.C. Individual differences in the acceptance of stereotyping. *J. Res. Pers.* **2006**, *40*, 1103–1118. [CrossRef]
2. Bordalo, P.; Coffman, K.; Gennaioli, N.; Shleifer, A. Stereotypes. *Q. J. Econ.* **2016**, *131*, 1753–1794. [CrossRef]
3. Bodenhausen, G.V.; Sheppard, L.A.; Kramer, G.P. Negative affect and social judgment: The differential impact of anger and sadness. *Eur. J. Soc. Psychol.* **1994**, *24*, 45–62. [CrossRef]
4. Brubaker, T.H.; Powers, E.A. The Stereotype of "Old"—A Review and Alternative Approach. *J Gerontol.* **1976**, *31*, 441–447. [CrossRef] [PubMed]
5. Karimi, M.; Hedner, J.; Lombardi, C.; Mcnicholas, W.T.; Penzel, T.; Riha, R.L.; Rodenstein, D.; Grote, L.; the Esada Study Group. Driving habits and risk factors for traffic accidents among sleep apnea patients—A European multi-centre cohort study. *J. Sleep Res.* **2014**, *23*, 689–699. [CrossRef]
6. Auriault, F.; Brandt, C.; Chopin, A.; Gadegbeku, B.; Ndiaye, A.; Balzing, M.-P.; Thollon, L.; Behr, M. Pregnant women in vehicles: Driving habits, position and risk of injury. *Accid. Anal. Prev.* **2016**, *89*, 57–61. [CrossRef] [PubMed]
7. Parc, C.; Tiberghien, E.; Pierre-Kahn, V. Driving habits in glaucoma patients. *J. Fr. Ophtalmol.* **2012**, *35*, 235–241. [CrossRef]
8. Kennedy, M.T.; Roche, S.; Lenehan, B.; Curtin, W. Driving plastered: Driving habits of orthopaedic outpatients and the medico-legal implications. *Eur. J. Orthop Surg. Traumatol.* **2006**, *16*, 228–230. [CrossRef]
9. Shakerinia, I.; Mohammadpoor, M. Relationship Between Psychological Characteristics Mental Health, Aggression and Driving Habits in Dangerous Drivers. *SSU J.* **2010**, *18*, 225–233. Available online: https://jssu.ssu.ac.ir/article-1-1096-en.html (accessed on 11 March 2023).
10. McGuire, F.L. Drinking and Driving Habits of Californians. *Am. J. Drug Alcohol Abus.* **2009**, *8*, 541–548. [CrossRef]
11. Bjerre, B.; Thorsson, U. Is an alcohol ignition interlock programme a useful tool for changing the alcohol and driving habits of drink-drivers? *Accid. Anal. Prev.* **2008**, *40*, 267–273. [CrossRef]
12. Gallo, J.J.; Rebok, G.W.; Lesikar, S.E. The driving habits of adults aged 60 years and older. *J. Am. Geriatr. Soc.* **1999**, *47*, 335–341. [CrossRef] [PubMed]
13. Bhattacharya, S.; Diaz, K. Driving Habits of Older Adults. *Kansas J. Med.* **2012**, *5*, 134–141. [CrossRef]
14. Bishu, R.R.; Foster, B.; McCoy, P.T. *Driving Habits of the Elderly—A Survey*; SAGE: New York, NY, USA, 2016; Volume 2, pp. 1134–1138. [CrossRef]
15. Chu, X. The Effects of Age on the Driving Habits of the Elderly: Evidence from the 1990 Npts. CUTR Research Reports. 1994. Available online: https://digitalcommons.usf.edu/cutr_reports/164 (accessed on 11 March 2023).
16. Sengupta, S.; van Landingham, S.W.; Solomon, S.D.; Do, D.V.; Friedman, D.S.; Ramulu, P.Y. Driving Habits in Older Patients with Central Vision Loss. *Ophthalmology* **2014**, *121*, 727–732. [CrossRef] [PubMed]

17. Owsley, C.; Stalvey, B.; Wells, J.; Sloane, M.E. Older Drivers and Cataract: Driving Habits and Crash Risk. *J. Gerontol. Ser. A* **1999**, *54*, M203–M211. [CrossRef]
18. Bauer, M.J.; Adler, G.; Kuskowski, M.A.; Rottunda, S. The Influence of Age and Gender on the Driving Patterns of Older Adults. *J. Women Aging* **2003**, *15*, 3–16. [CrossRef]
19. Gwyther, H.; Holland, C. The effect of age, gender and attitudes on self-regulation in driving. *Accid. Anal. Prev.* **2012**, *45*, 19–28. [CrossRef]
20. González-Iglesias, B.; Gómez-Fraguela, J.A.; Luengo-Martín, Á. Driving anger and traffic violations: Gender differences. *Transp. Res. Part F Traffic Psychol. Behav.* **2012**, *15*, 404–412. [CrossRef]
21. Varga, G. *Navigációs rendszerek használata: Felhasználói szokások és interakciók vizsgálata*; BME Mob Innovációs Központ: Budapest, Hungary, 2011; p. 185.
22. Al Mahmud, A.; Mubin, O.; Shahid, S. User experience with in-car GPS navigation systems. In Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services, Bonn, Germany, 15–18 September 2009; pp. 1–2.
23. Hu, S.; Su, L.; Li, S.; Wang, S.; Pan, C.; Gu, S.; Al Amin, M.T.; Liu, H.; Nath, S.; Choudhury, R.R.; et al. Experiences with eNav: A Low-power Vehicular Navigation System. In Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing, Osaka, Japan, 7–11 September 2015; pp. 433–444.
24. Nakhimovsky, Y.; Miller, A.T.; Dimopoulos, T.; Siliski, M. Behind the scenes of google maps navigation. In Proceedings of the CHI '10 Extended Abstracts on Human Factors in Computing Systems, Atlanta, GA, USA, 10–15 April 2010; pp. 3763–3768.
25. Wang, L.; Ju, D.Y. Concurrent Use of an In-vehicle Navigation System and a Smartphone Navigation Application. *Soc. Behav. Pers. Int. J.* **2015**, *43*, 1629–1640. [CrossRef]
26. Gardner, R.C. Stereotypes as Consensual Beliefs. In *The Psychology of Prejudice (The Ontario Symposium on Personality and Social Psychology)*; Zanna, M.P., Olson, J.M., Eds.; Lawrence Erlbaum: Hillsdale, NJ, USA, 1994; Volume 7, pp. 1–31.
27. Hamilton, D.L.; Sherman, J.W. Stereotypes. In *Handbook of Social Cognition*; Wyer, R.S., Srull, T.K., Eds.; vol. 2: Ap. Aufl.; Erlbaum: Hillsdale, NJ, USA, 1994; pp. 1–68.
28. Hilton, J.L.; Von Hippel, W. Stereotypes. *Annu. Rev. Psychol.* **1996**, *47*, 237–271. [CrossRef]
29. Bodenhausen, G.V.; Kramer, G.P.; Süsser, K. Happiness and stereotypic thinking in social judgment. *J. Pers. Soc. Psychol.* **1994**, *66*, 621–632. [CrossRef]
30. Kite, M.E.; Stockdale, G.D.; Whitley, B.E.; Johnson, B.T. Attitudes Toward Younger and Older Adults: An Updated Meta-Analytic Review. *J. Soc. Issues* **2005**, *61*, 241–266. [CrossRef]
31. Joanisse, M.; Gagnon, S.; Voloaca, M. Overly cautious and dangerous: An empirical evidence of the older driver stereotypes. *Accid. Anal. Prev.* **2012**, *45*, 802–810. [CrossRef]
32. Chapman, L.; Sargent-Cox, K.; Horswill, M.S.; Anstey, K.J. The Impact of Age Stereotypes on Older Adults' Hazard Perception Performance and Driving Confidence. *J. Appl. Gerontol.* **2016**, *35*, 642–652. [CrossRef] [PubMed]
33. Levy, B.R. Mind Matters: Cognitive and Physical Effects of Aging Self-Stereotypes. *J. Gerontol. Ser. B* **2003**, *58*, 203–211. [CrossRef] [PubMed]
34. Pravossoudovitch, K.; Martha, C.; Cury, F.; Granié, M.A. Sex and age differences in the endorsement of sex stereotypes associated with driving. *Span. J. Psychol.* **2015**, *18*, E100. [CrossRef]
35. Granié, M.A.; Papafava, E. Gender stereotypes associated with vehicle driving among French preadolescents and adolescents. *Transp. Res. Part F Traffic Psychol. Behav.* **2011**, *14*, 341–353. [CrossRef]
36. Özkan, T.; Lajunen, T. What causes the differences in driving between young men and women? The effects of gender roles and sex on young drivers' driving behaviour and self-assessment of skills. *Transp. Res. Part F Traffic Psychol. Behav.* **2006**, *9*, 269–277. [CrossRef]
37. Helton, L. Does This Bumper Sticker Make Me Look Reckless? Stereotypes About Driving Ability Based on Perceived Gender. Available online: https://mcstor.library.milligan.edu/handle/11558/5878 (accessed on 11 March 2023).
38. Kadulina, Y. Eat My Dust: Stereotypes about Female Drivers Persist but Do Not Affect Their Driving. Ph.D. Thesis, University of Ottawa, Ottawa, ON, Canada, 2022.
39. Dontsov, A.I.; Kabalevskaya, A.I. Gender stereotypes among road users. *Psychol. Russ. State Art* **2013**, *6*, 150–163. [CrossRef]
40. Wilson, J. *Essentials of Business Research: A Guide to Doing Your Research Project*, 2nd ed.; Seaman, J., Ed.; SAGE Publications Ltd.: Thousand Oaks, CA, USA, 2014; 339p.
41. Tavakol, M.; Sandars, J. Quantitative and qualitative methods in medical education research: AMEE Guide No 90: Part II. *Med. Teach.* **2014**, *36*, 838–848. [CrossRef] [PubMed]
42. Boncz, I. *Kutatásmódszertani Alapismeretek*; Sebestyén, A., Ed.; Pécsi Tudományegyetem Egészségtudományi Kar: Pécs, Hungary, 2015; 290p.
43. McClelland, S.B. Training Needs Assessment Data-gathering Methods: Part 1, Survey Questionnaires. *J. Eur. Ind. Train.* **1994**, *18*, 22–26. [CrossRef]
44. Stone, D.H. Design a questionnaire. *Br. Med. J.* **1993**, *307*, 1264–1266. [CrossRef] [PubMed]

45. Foddy, W. Constructing Questions for Interviews and Questionnaires. In *Theoryand Practice in Social Research*; Cambridge University Press: Cambridge, UK, 1993. Available online: https://books.google.hu/books?hl=hu&lr=&id=tok_OKwywQIC&oi=fnd&pg=PP9&dq=Foddy,+%5CV,+(1993)+Constructing+QuestionsforInterviews+and+Questionnaires.+Theoryand+Practice+in+Social+Research.+Cambridge,+UK:+Cambridge+University+Press&ots=TA8gi9S1JI&sig=Z4cRKO (accessed on 11 March 2023).
46. Dillman, D. *Mail and Internet Surveys. The Tailored Design Method*; John Wiley & Sons, Inc.: New York, NY, USA, 2000.
47. Fink, A. *How to Ask Survey Questions*, 2nd ed.; Sage Publications, Inc.: Thousand Oaks, CA, USA, 2003; 143p.
48. Brislin, R.W. The wording and translation of research instruments. In *Field Methods in Cross-Cultural Research*; Loner, W.J., Berry, J.W., Eds.; Sage: Newbury Park, CA, USA, 1986; pp. 137–164.
49. Oppenheim, A.N. *Questionnaire Design, Interviewing and Attitude Measurement*; Pinter: London, UK, 1992.
50. Dörnyei, Z.; Taguchi, T. *Questionnaires in Second Language Research: Construction, Administration, and Processing*, 2nd ed.; Questionnaires in Second Language Research; Routledge: New York, NY, USA, 2009; pp. 1–185. Available online: https://www.taylorfrancis.com/books/mono/10.4324/9780203864739/questionnaires-second-language-research-zoltán-dörnyei-tatsuya-taguchi (accessed on 11 March 2023).
51. Lietz, P. Research into Questionnaire Design: A Summary of the Literature. *Int. J. Mark. Res.* **2010**, *52*, 249–272. [CrossRef]
52. Parahoo, K. Focus Groups: Kader Parahoo on Why Focus Groups Are Enjoying Increased in Popularity as a Research Method—Document—Gale OneFile: Health and Medicine. *Nurse Res.* **2007**, *14*, 4. Available online: https://go.gale.com/ps/i.do?id=GALE%7CA159593148&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=13515578&p=HRCA&sw=w&userGroupName=anon~492dd5b1 (accessed on 11 March 2023). [CrossRef]
53. Lehota, L. *Marketingkutatás az agrárgazdaságban*; Mezőgazda Kiadó: Budapest, Hungary, 2001; pp. 49–51.
54. Johnson, T.P. Snowball Sampling: Introduction. In *Wiley StatsRef: Statistics Reference Online*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2014; pp. 12–14.
55. Parker, C.; Scott, S.; Geddes, A. *SAGE Research Methods Foundations*; SAGE Publications Ltd.: London, UK, 2020. Available online: https://methods.sagepub.com/foundations (accessed on 11 March 2023).
56. Vörös, F.; Gartner, G.; Peterson, M.P.; Kovács, B. What Does the Ideal Built-In Car Navigation System Look Like?—An Investigation in the Central European Region. *Appl. Sci.* **2022**, *12*, 3716. [CrossRef]

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A Study on Temporal and Spatial Differences in Women's Well-Being in an Ecologically Vulnerable Area in Northwest China

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Abstract: As an important driving force for economic development and social progress, women have become an important subject of well-being research. Human well-being is the state of physical and mental health as well as material affluence and includes a variety of factors, such as wealth, education, health, safety, amenities, way of life, and happiness. Based on the established research framework of the Women's Development Index (WDI) in Northwest China, this paper first measured the objective well-being level of women in Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang from 2003 to 2020 under the influence of ecological factors. In addition, spatial disaggregation and comparative analyses of the spatial imbalance of women's well-being in Northwest China were carried out using the Theil index and Dagum Gini coefficient. The results show that (1) the WDI in ecologically vulnerable areas in Northwest China increased from 0.525 in 2003 to 0.690 in 2020, indicating an overall increase in well-being. (2) The WDI in the five provinces gradually increased with fluctuations. Among them, Shaanxi always remained in first place in terms of the WDI. (3) From 2003 to 2020, the spatial imbalance of women's well-being as measured according to the WDI in Northwest China first increased and then decreased. However, the gap in women's well-being in Northwest China was smaller than the economic gap. (4) From 2003 to 2020, the well-being gap measured by the WDI among the 10 groups of provinces in Northwest China gradually decreased, and the development gap between the provinces and Shaanxi was the largest.

Keywords: Northwest China; ecologically vulnerable areas; objective well-being; Women's Development Index; unbalanced space

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1. Introduction

Clear waters and green mountains are as good as mountains of gold and silver. The improvement in human well-being is the ultimate objective of sustainable development [1]. The essential objective of enhancing the well-being of Chinese citizens entails the promotion of gender equality and the all-around development of women's welfare. The improvement in women's well-being along with a focus on women's developmental environments have gained importance in China since the Outline for Women's Development in China (2021–2030) was published in 2021. The ecologically sensitive regions of Northwest China benefit from national development plans thanks to the promotion of national strategies such as the Western Development Strategy and the Silk Road Economic Belt, resulting in a significant increase in the economy and improvement in human well-being. Scientific problems that must be addressed include how to quantify human well-being objectively, with a particular emphasis on the development status of women and geographical differences, as well as how to increase the well-being of women in Northwest China.

Human well-being has many different meanings and is frequently used to assess and develop human lifestyles. It is sometimes referred to as happiness, human welfare, the standard of living, or quality of life [2]. The study of human well-being has advanced significantly. Previous scholars used the Physical Quality of Life Index (PQLI) [3], the

Human Development Index (HDI) [4], and multidimensional indicators [5] to measure the level of well-being in various regions, considering, for example, urban and rural areas within different regions [6–8] or economic belts. Women's well-being is a part of the study of human well-being, which is often associated with education, work, physical health, and mental health. To further investigate the content and focus of the study on women's well-being, literature-analysis applications such as VOSviewer and Pajek were used to conduct a visual clustering analysis on the keywords.

First, we conducted a comprehensive search of the literature on "women well-being" in the Web of Science's core database from 2000 to 2023, yielding 31,836 items. We searched the literature connected to this study in order to analyze it. The screening criteria for literature were paper, review paper, and online publication, and the screening topic areas were Geography, Humanities Multidisciplinary, Environmental Sciences, Sociology, Environmental Studies, Urban Studies, Geography Physical, and Social Issues. A total of 1801 articles and 1805 keywords were screened out. We carried out keyword-co-occurrence analysis on the keywords that appeared five times or more in each article to analyze keyword clustering. The threshold was fulfilled by 603 keywords. The research themes were characterized as gender, health, mental health, family and work, personality, psychological well-being, and pregnancy, with eight key-word clusters of female well-being acquired. These addressed psychological, physiological, and social well-being. The current research on women's well-being is an exploration of gender perspectives, focusing on the health problems of various groups, such as the elderly, pregnant women, and working women, and taking into account the influence of family, employment, children, and other factors on women's well-being. We discovered that the health and employment characteristics of various groups of women were highly connected to women's well-being through a thorough study of key phrases in the literature relevant to women's well-being. There were indices developed for measuring women's well-being. The California Budget & Policy Center, for example, has developed the California Women's Well-Being Index, which is a multifaceted, composite measure consisting of five "dimensions" including health, personal safety, employment & earning, economic security, and political empowerment [9]. The United Nations has created the Gender Disparity Index, which encompasses variables including, the freedom of movement, property rights, freedom to work, and financial rights [10] A recent study has developed a set of indicators on women's health and well-being, such as women's living conditions, decision making power, reproductive health, fertility, and issues related to domestic violence [11] (Figure 1).

Sociologists also gave attention to research on women's well-being in addition to the diverse indicator systems developed by various international organizations for measuring women's well-being in the current study [12]. Those who have explored influencing factors from the perspective of gender equality [13] have also conducted research on gender well-being differentiation. Researchers have utilized methods such as emotional balance scales [14], life satisfaction scales [15], and mathematical models [16–19] to measure the well-being levels of women in various age groups [20], with different employment statuses [21,22] and different health statuses [23]. Nevertheless, spatial and temporal expressions of women's well-being status in the regional dimension were lacking. Scholars have advanced the indicators by incorporating ecological aspects into the HDI in response to the environment's growing effect on human existence [24,25]. Both domestic and international scholars have developed indicator systems to measure the level of well-being of residents in accordance with the status of ecosystem services in various natural regions [26–30] since the Millennium Ecosystem Assessment report proposed the contribution of ecosystem services to human well-being. A review of related studies elucidated the following: ① Currently, studies on well-being have developed a variety of indicator systems that cover health well-being [31–35], psychological well-being [36–41], social well-being [42–46], and other aspects [47,48]. There has also been some exploration into the perspective of ecological impacts [49–51]. Although all individuals, without distinction by gender, were research subjects in the bulk of these studies, these studies gave less attention to female

groups and neglected the effects of ecological variables. ② The study of women's objective well-being has not yet developed a complete system due to a lack of analysis of temporal and spatial changes from a geographical perspective and of the comparison of disparities among geographical areas. In recent years, the well-being measurement of female groups has primarily focused on the exploration of subjective well-being and influencing factors in qualitative research [52–55].

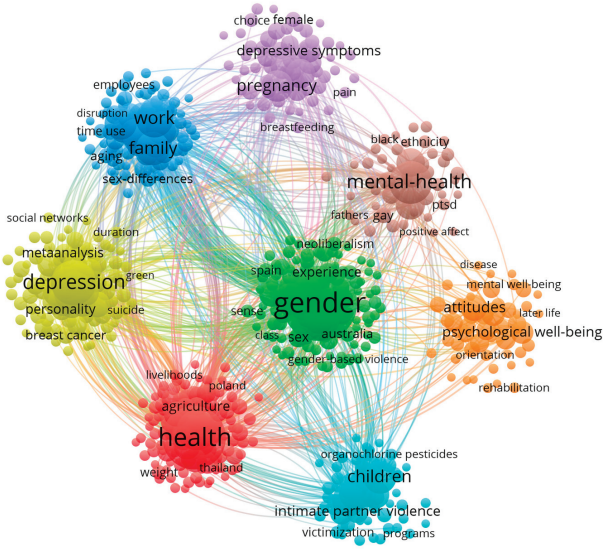


Figure 1. Hotspot-Label View of Women's Well-being Research from 2000 to 2023.

With the degree of social and economic development being lower than that of eastern China, Northwest China is a fragile environmental area. At the county and provincial levels, some researchers have already explored the ecological vulnerability of Northwest China using data on nighttime illumination and the construction of multidimensional indicators [56]. However, there are few studies on human well-being in this ecologically vulnerable area that assess the regional development level, and there is no attention given to the residents of this area. The Blue Book of Western Region of China was extended on the development status and institutional factors of women in Northwest China, pointing out that the main factors restricting the development of women in Northwest China were health, education, employment, and unbalanced regional development [57]. The majority of studies on women in Northwest China at the moment concentrate on pregnant women [58], liushou women, etc., assessing their physical health from a medical perspective. The region's present water crisis is a topic of interest for certain academics. In Northwest China [59], there is currently a lack of macro-measurements as well as temporal and spatial changes in women's well-being. The degree of women's development and well-being in this region should be given more consideration because the majority of men in Northwest China have moved to the east of the nation due to a lack of work opportunities and poor wages [60]. In view of China's widening east-west developmental divide, it is crucial to investigate and assess the study of women's well-being in ecologically vulnerable areas.

The three dimensions of the HDI, namely, health, income, and education, were used in this study, along with data from five provinces in Northwest China from 2003 to 2020. The indicator layer of the HDI was further enhanced using the gender-equality and women's advancement indicators developed by previous researchers [61]. The special section of the Human Growth Report on the 40th Anniversary of Reform and Opening Up notes that the low level of industry, limited production efficiency, excessive resource consumption, and pollution emissions were additional significant factors impeding Northwest

China's development. Therefore, in this paper, ecological conditions were added as a significant influencing factor to the study of well-being. To provide guidance for high-quality transformative development in Northwest China from a gender perspective and to provide reference and empirical evidence for improving the well-being of women in less-economically developed regions, the changes in the objective well-being of women in Northwest China and the degree of regional imbalance were measured.

2. Materials and Methods

2.1. Study Area

Northwest China (73°15′–111°15′ E, 31°32′–49°10′ N) includes five provinces and autonomous regions, namely, the Shaanxi, Gansu, Qinghai, Ningxia Hui, and Xinjiang Uygur Autonomous Regions, and it is an important area and strategic focus of China's Western Development Strategy [62] and the Silk Road Economic Belt [63]. To depict the location status and the types of ecosystems of Northwest China, we created Figure 2 using information from the Resource and Environment Science and Data Center [64]. Northwest China covers an area of 3,083,900 square kilometers, accounting for approximately one-third of China's land area, with an average altitude of 3,200 meters, rich mineral resources, scarce precipitation, low forest coverage, fragile ecological environment, and sensitivity to climate change [65]. To show the natural environment and socioeconomic economy in Northwest China in 2020, we created Table 1 based on data from the China Statistical Yearbook [66]. The population of the five provinces exceeded 100 million in 2020, with clusters of Hui, Uyghur, and other ethnic minorities. The male population represented a slightly higher proportion than the female population; 7.18% of the female population aged 15 and above were illiterate, a much higher figure than the national level of 4.95%; and approximately 43% of the female population were employed. Among them, the education level of employed women was concentrated at the primary and junior high school levels, which was lower than that of employed women in the developed eastern regions of China. In 2020, the gross domestic product of Northwest China was 5592.256 billion yuan, and the proportion of secondary and tertiary industries accounted for approximately 90% of the regional GDP (Table 1). In the new period of rapid economic transformation and development, Northwest China has been characterized by sluggish industrial development, poor guidance of advanced technologies, heavy resource consumption, and pollution emissions, in addition to prominent human-land conflicts. The level of and changes in people's well-being in the region were scientific issues that need urgent attention; in particular, disadvantaged groups, including women, should be given more extensive attention.

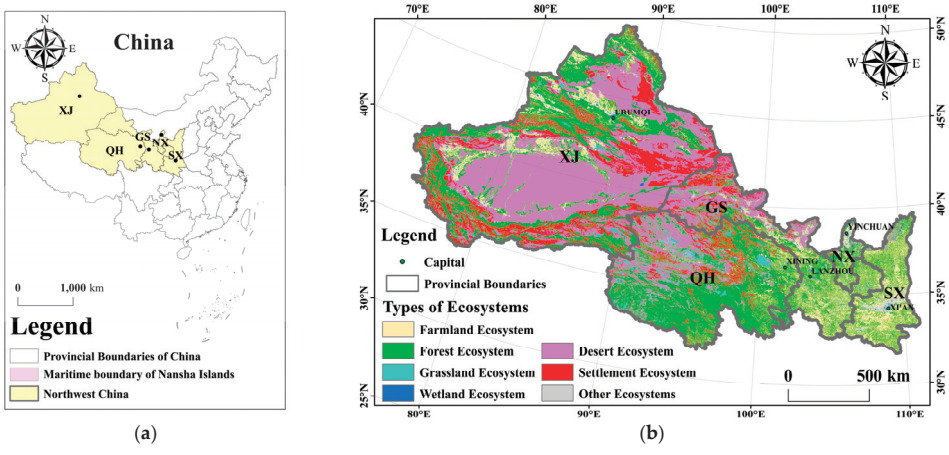


Figure 2. Study Area. (**a**) The location of Northwest China in China; (**b**) Types of Ecosystems in Northwest China.

Table 1. Natural Environment and Social Economy in Northwest China in 2020.

	Total Land Area (10,000 km^2)	Terrain	Hydrological Conditions	Climate Type	Average Annual Precipitation (mm)	Forest Cover (%)
Shaanxi	20.56	Highlands, plains, and mountains	Yellow River, Yangtze River	Temperate, subtropical monsoon climate	760.50	43.06
Gansu	42.58	Highland	Yellow River, Yangtze River, and Inland rivers	Monsoonal climate, continental climate, highland mountain climate	450.30	11.28
Qinghai	72.12	Highland	Yangtze River, Yellow River, and The origin of the Lancang River	Highland continental climate	338.90	6.30
Ningxia	6.64	Highlands, plains, and mountains	Yellow River	Temperate continental climate	331.60	11.89
Xinjiang	166.49	Basin, mountains	Glacial snow, in-stream, and out-stream rivers	Temperate continental climate	192.40	4.24
	Total production value (billion yuan)	**The proportion of primary industry**	**The proportion of secondary and tertiary industries**	**Secondary and tertiary industry employment (10,000 people)**	**Per capita disposable income (yuan)**	
Shaanxi	26181.86	8.66%	91.34%	1473	26226.0	
Gansu	9016.70	13.29%	86.71%	734	20335.1	
Qinghai	3005.9	11.12%	88.88%	208	24037.4	
Ningxia	3920.5	8.62%	91.38%	261	25734.9	
Xinjiang	13797.6	14.36%	85.64%	896	23844.7	
Total	55922.56			3572		
	Year-end Population (10,000 persons)	**Male population share (%)**	**Female population share (%)**	**Urban Population Density (People/km^2)**	**Code**	
Shaanxi	3955	51.2	48.8	4985	SX/S	
Gansu	2502	50.76	49.8	3235	GS/G	
Qinghai	592	50.3	49.7	2930	QH/Q	
Ningxia	720	50.94	49.06	3153	NX/N	
Xinjiang	2585	48.3	51.7	3627	XJ/X	
Total	10354				NC	

2.2. Framework and Methods

This study employs a provincial scale to assess the well-being of women in the Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang Provinces between 2003 and 2020, focusing on the environmentally vulnerable region in Northwest China. To assess the degree of women's well-being in this region, this study created the Women's Development Index (WDI) in Northwest China (Figure 3). It was then compared with the women's HDI, which only uses 3 indicators (Health: Life expectancy, Income: Disposable income, Education: Average years of education) in this region and used to analyze their differences. The three aspects of health, income, and education from the HDI were employed in this article under the WDI index to ensure the scientific proportion of each dimension of the index. The three dimensions' index levels are enriched in this study. We searched and analyzed the gender indicators used by 32 major developed and developing countries or cities, 5 international organizations (the United Nations, the World Bank, the United Nations Economic Commission for Europe, the International Labor Organization, and the European Union), and Chinese scholars' methods to measure the status of female development and gender equality in order to choose the most appropriate indicators. Indicators used more frequently in the health dimension included the life expectancy according to sex, maternal mortality rate, detection rate of women's diseases, and percentage of smokers by sex; those in the income dimension included female disposable income, female unemployment rate, and female employment rate in other units; and those in the education dimension included the female college-enrollment percentage, literacy rate, and illiteracy rate. Considering the present state of

women's advancement in Northwest China, regional development restrictions, and data accessibility, the following three dimensions were used to enrich the three HDI dimensions of health, income, and education: The health index (HI) assesses women's life expectancy at birth (X1), the maternal mortality rate (X2), and detection rate of gynecological diseases (X3). The employment index (EMI) assesses the employment rate of urban women in other ownership units (X4) and female unemployment rate. The education index (EI) assesses the average years of education for women (X13), the illiteracy rate of women over 15 years old (X14), and the percentage of women among college students.

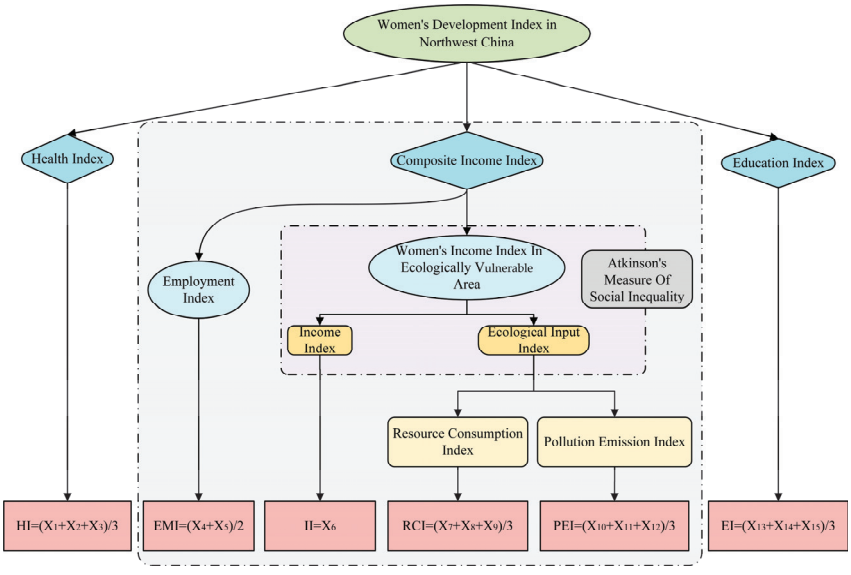


Figure 3. The Framework of the WDI Under the Influence of Ecological Factors in Northwest China.

This study took into account Northwest China's extensive development and ecological vulnerability. The region's serious resource consumption and pollution discharge were significant development-restraining issues [67]. We penalized the revenue component by factoring in the environmental costs of production. Income has typically been included in the HDI because it offers access to basic necessities of life as well as other products and services that help people realize their full potential. However, it is widely accepted that this potential must be ensured not just for the current generation, but also for future generations. Human, physical, and environmental capital must all be replenished. Current income figures do not account for the costs of manufacturing, such as pollution and decreased quality of life. The values used to compute income were simply added together; nothing was deducted. Per capita carbon emission was once employed by academics as a measurement or index of ecological input. The ecological input index (EII) was enriched in this study. The resource consumption index (RCI) took into account the water resource consumption index, land resource consumption index, and energy consumption index, and was measured by assessing women's water consumption (X7), the female per capita built-up area (X8) and carbon emissions per woman (X9), respectively. The pollution emission index(PEI)takes into account the water pollution discharge index, land pollution discharge index, and air pollution discharge index, using female per capita wastewater discharge (X10), the solid waste per woman (X11), and exhaust emissions per woman (X12), respectively. As a result, this research alters the previous study, which exclusively calculated regional well-being according to positive indicators by using resource consumption and pollution emissions as environmental indicators and including them in the income component as the expense (cost) of output growth. The income-index dimension

incorporates environmental-effect variables as production costs into the income index using the approach of Atkinson's measure of inequality, combining the women's income index in ecologically vulnerable areas and EI to create the composite income index (CII) [68].

This study makes reference to the methodical basis of index assignment used by scholars such as Yibin S. and Yunzhu J. [69] to measure the gender equality and women's development in China. By maintaining the stability of the indicators and abiding by the scientific percentage of the HDI, subjective values were assigned to each indication during the weighting of the WDI indicators. According to the value assignment principle, the three aspects of health, income, and education each have a sum of values that equals 1. From the level of the HI in WDI, to maintain the importance of female life expectancy (X1) in the HDI, we assigned it a value of 0.5, supplemented by other indicators with a total weighting of 0.5 and, thus, contributing 0.25 to maternal mortality rate (X2) and 0.25 to the rate of detection rate of gynecological diseases (X3). From the index layer of EI in WDI, in order to maintain the importance of average years of education for women (X13) in the HDI, we assigned it a value of 0.5 and, supplementarily, the total empowerment value of other indicators a value of 0.5. Therefore, the Illiteracy rate of females over 15 years old (X14) and the percentage of women among college students (X15) were both assigned the value of 0.25. From the index layer of CII in WDI, the original value of female disposable income should be 0.5 in order to maintain the importance of female disposable income per capita (X6) in HDI. However, the measurement of ecological factors were added in the calculation of the CII in this paper. To highlight the importance of ecological factors to the CII, we assigned a value of 0.7 and a value of 0.3 to the EI. The employment rate of urban women in other ownership units and female unemployment rate should both be assigned the value of 0.15, respectively. It should be noted that in WDI, the higher the value of X2 and X3 in HI, X5 in CII, and X14 in EI, the lower the corresponding value of HI, CII, and EI. Therefore, for convenience of calculation, we subtracted the normalized value from 1 after the standardized calculation of indicators to get the specific value in this index system.

Data for each index from 2003 to 2020 were sorted. In this study, the maximum and minimum values of indicators were set in accordance with the principle of HDI. The minimum value was set as the minimum value not reached by the development of each province, and their maximum values were set at the highest unreached and nearest values for each year. The human development report provided the maximum and lowest ranges for X1, X6, and X13. The maximum and minimum values for X2-X5, X7-X12 and X14-X15 were then defined. From the point of view of the minimum value setting, the per capita CO_2 emission index [67] was used in the dimension of ecological input with reference to Lasso when measuring the pollution sensitive HDI of each country, and the minimum value was defined as 0. Obviously, the social production in Northwest China already has a certain degree of resource consumption and pollution emission, but in recent years, the emission of all indicators has shown a downward trend. We forecasted the future development of the region in the direction of sustainable green development from the perspective of ideal development. The value of RCI and PEI may be getting closer and closer to 0. We undoubtedly did not exclude the possibility of a green-manufacturing method in the future to reduce resource usage and environmental emissions. Hence, the minimum values of X7-X12 were set as 0. The minimum values of X2-X5 and X14-X15 were set as 0 according to the definition of minimum value in HDI. When determining the maximum value, we looked at each indicator's change and trend in each of the five provinces, determined each indicator's peak value, and forecasted the future in light of the state of regional development. We chose a maximum value that was just a little bit higher than the peak value since the maximum likelihood would not go above the peak value. Therefore, the maximum values of X2-X5, X7-X12, and X14-X15 from 2003 to 2020 are as follows: XJ:138.55(2003); NX:54(2008); SX:53(2020); QH:23.2(2003); XJ:2787(2012); NX:271396(2018); NX:29(2019); NX:33(2009); XJ/QH:59(2006)/28473(2016); NX:245407(2010);QH:33(2005); and SX:58(2017). Then, we set the maximum of X2-X5, X7-X12, and X14-X15 for 140, 60, 60, 30, 2850, 300000, 30, 35, 70/30000, 260000, 35, 30 (Table 2).

Table 2. The Range of Each Indicator Layer.

Dimensional Layer		Indicator Layer	Weight	Minimum Value	Maximum Value
Long and Healthy Life	X_1	Life expectancy for women/year	0.5	20	85
	X_2	Maternal mortality rate 1/100,000	0.25	0	140
	X_3	Detection rate of gynecological diseases (%)	0.25	0	60
Standard of living	X_4	Employment rate of urban women in other ownership units (%)	0.15	0	60
	X_5	Female unemployment rate (%)	0.15	0	30
	X_6	Female disposable income per capita/yuan		352.4	264,300
Resource Consumption	X_7	Women's water consumption (m^3/person)	0.7	0	2850
	X_8	Female per capita built-up area (m^2/person)		0	300,000
	X_9	Carbon emissions per woman (tons/person)		0	30
Pollution Emission	X_{10}	Female per capita wastewater discharge (tons/person)		0	35
	X_{11}	Solid waste per woman (kg/person)		0	70/30,000
	X_{12}	Exhaust emissions per woman (m^3/person)		0	260,000
Knowledge	X_{13}	Average years of education for women/year	0.5	0	15
	X_{14}	Illiteracy rate of females over 15 years old (%)	0.25	0	35
	X_{15}	Percentage of women among college students (%)	0.25	0	30

2.3. Research Methods and Calculations

The key algorithms used in this research involved, separately, the techniques of Atkinson's measure of inequality [70], the Theil index [71], and the Dagum Gini coefficient [72] in the calculation of the environmental income index and the estimation of geographical imbalance.

2.3.1. Calculation of the WDI

(1) Calculation of each indicator

Standardization of indicators. Just as in the index of HDI, to construct WDI, it is necessary to convert the value of different combinations into an index and then obtain the geometric mean of HI, CII, and EI. To unify all indicators to the same scale, the first step was to calculate the values of all factors from 2003 to 2020 to 0–1 in a unified way. According to the maximum value and minimum value range stipulated in this paper, the calculation formula of each dimension's index is as follows:

$$VALUE = \frac{Actual\ value - min}{max - min} \tag{1}$$

$$Income\ index = \frac{\ln X6 - \ln X6_{min}}{\ln X6_{max} - \ln X6_{min}} \tag{2}$$

The values of the indicators X1–X5; X7–X15 were calculated according to Equation (1). The X6 was calculated by the Equation (2).

(2) Calculation of the Women's Income Index in an Ecologically Vulnerable Area

The EII, which ranges in value from 0 to 1, was created by the arithmetic-average processing of the six indicators of resource consumption and pollution emissions. The lower the value is, the lower the ecological cost of regional development; the higher the value is, the greater the ecological consumption and burden.

$$EII = \frac{RCI + PEI}{6} \tag{3}$$

$$EBI = 1 - EII \tag{4}$$

(3) EII is an environmental damage index that was created using the same methodology as the Environmental Behavior Index (EBI) by Lasso et al. We chose to change the EII and create an EBI in order to produce a positive assessment of the good management of nature

because the indicators used in the HDI place a positive value on development, whereas this index does the reverse (which in this case means not consuming resources and polluting the environment). The negative index (EII) should be adjusted to the positive index (EBI).

After II and EBI were calculated, we combined them into a single index as part of the CII, which we called M_3P. In areas with high levels of RCI and PEI, EBI was close to 0, so there was a large negative impact on income, and thus, WDI values are sacrificed. Similarly, if a province's EII close to 0, it must have a positive impact on the assessment of income. To incorporate measures of EBI into II, we referred to Atkinson's measure of inequality.

$$M_3P(e) = \left[\frac{(M_3)^{1-e}}{2} + \frac{(EBI)^{-1}}{2} \right]^{\frac{1}{1-e}} \quad (5)$$

The value of e changes between 0 to infinite, reflecting the extent of the dislike of inequality. If e = 0, there is no penalty (loss), and the result is a simple arithmetic average of Equation (5). As e increased, the women's income index in an ecologically vulnerable area decreased, and the II and EII of inequality increased. At the other extreme, where e is equal to infinity, income is quite sensitive to the environment, and the two values both reach the minimum. In any case, where the two components have the same value, the M_3P result is the arithmetic average, which means no inequality.

Since the harmonic mean is lower than the arithmetic mean when the income index is inconsistent with the environmental behavior index, the harmonic mean of the two indexes was taken for the calculation in this paper. According to this standard, e was set as 2, and the calculation formula of M_3P was as follows:

$$M_3P = \left[\frac{(M_3)^{-1}}{2} + \frac{(EBI)^{-1}}{2} \right]^{-1} \quad (6)$$

This calculation may seem complicated, but the basic principle is simple. In this research study, it was assumed that people have a neutral aversion to environmental damage. The method of synthesizing the various components into an index with a weight of $\varepsilon = 2$ has also been used in Human Development reports (for example, in the Human Poverty Index and Gender Empowerment Index measurements of the Gender Development Index).

2.3.2. Spatial Imbalance Measurement

Theil's index calculates inequality and differences based on entropy and information-quantity concepts. It breaks down the overall difference into differences between and within subregions, which has several applications in the analysis and study of differences and imbalance. To address the limitations of both the classic Gini coefficient and the Theil index, Dagum suggested a novel approach (the Dagum Gini coefficient) to further deconstruct the Gini coefficient of inequality [73]. When used to calculate regional differences, the Dagum Gini coefficient solves the cross-overlap problem among the samples and fully takes into account the particular distribution of subsamples [74]. This study used the Theil index and the Dagum Gini coefficient to calculate the regional imbalance between the provinces based on the time-series change and the level of women's development in Northwest China.

(1) Theil index

The Theil index, which can be geographically decomposed, is frequently used to quantify regional differences. The total income under the women's ecological factor in Northwest China was calculated by multiplying the total population of Northwest China by the women's ecological factor income index. Similarly, the total WDI in Northwest China was calculated by multiplying the total population of Northwest China by the WDI.

Based on the degree of women's development (income) in Northwest China, the Theil index was calculated according to the following formula:

$$Theil_i = \frac{y_j}{Y} \lg \frac{\left(\frac{y_j}{Y}\right)}{\left(\frac{x_j}{X}\right)} \tag{7}$$

$$Theil = \sum_{i=1}^{n} \left(\frac{y_j}{Y}\right) lg \frac{\left(\frac{y_j}{Y}\right)}{\left(\frac{x_j}{X}\right)} \tag{8}$$

For Northwest China, each province and district's Theil index level is represented by Equation (7), while the total Theil index level is represented by Equation (8). The total women's development (income) level index and the total population of the j_{th} province, accordingly, are denoted by y_j and x_j, while Northwest China's entire population is denoted by y and x. For each province in Northwest China, the Theil index's positive value correlates inversely with the proportion of total regional development to the total population. Conversely, the Theil index's negative value correlates inversely with the proportion of total development to the total population.

(2) Dagum Gini coefficient

The Dagum Gini coefficient was presented to investigate the fluctuation of the Gini coefficient among provinces. In contrast to the conventional Gini coefficient and Theil index, Dagum proposed a measure of the Gini coefficient decomposed by subgroups, which divides the overall Gini coefficient into three components: the intraregional-variation contribution (G_w), the interregional net-variation contribution (G_{nb}), and the supervariable-density contribution (G_t). Given the benefits and features of the Dagum Gini coefficient decomposition, this approach was chosen to characterize the regional differences in the degree of women's development in Northwest China. The formulae are presented in Equations (5)–(15).

$$G = G_w + G_{rb} + G_t \tag{9}$$

$$G = \frac{\sum_{j=1}^{k} \sum_{h=1}^{k} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} \left| y_{ji} - y_{hr} \right|}{2un^2} \tag{10}$$

$$\overline{Y}_1 \le \overline{Y}_h \le \ldots \overline{Y}_j \le \ldots \overline{Y}_k \tag{11}$$

$$G_w = \sum_{j=1}^{k} G_{jj} p_j s_j \tag{12}$$

$$G_{jj} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} \left| y_{ji} - y_{jr} \right|}{2\overline{Y}_j n_j^2} \tag{13}$$

$$G_{nb} = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} \left(p_j s_h + p_h s_j \right) D_{jh} \tag{14}$$

$$G_{jh} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_k} \left| y_{ji} - y_{jr} \right|}{n_j n_h \left(\overline{Y}_j + \overline{Y}_h \right)} \tag{15}$$

$$G_t = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} \left(p_j s_h + p_h s_j \right) \left(1 - D_{jh} \right) \tag{16}$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{17}$$

$$d_{jh} = \int_0^\infty dF_j(y) \int_0^y (y - x) dF_h(x) \tag{18}$$

$$p_{jh} = \int_0^\infty dF_h(y) \int_0^y (y - x) dF_j(x) \tag{19}$$

When separating the subregions, the cross-term is what contributes to the overall disparity (hypervariable density or G_t), which in this case is zero, as there is no cross-

term. The province serves as the smallest unit of measurement; hence, G_w is also 0. This measurement is focused on calculating the Gini coefficient between provinces. To make the computation easier, each province's development level was taken into account while determining the Gini coefficient breakdown, as shown in Equation (11). In the formula above, u represents the level of overall development of women in the five provinces, y_{ji} (y_{hr}) represents the level of the development of women in any city in region j(h), n represents the total number of provinces, k represents the number of regions, and n_j (n_h) represents the number of provinces in region j(h). G_{jj} stands for the Gini coefficient within region j, G_{jh} for the Gini coefficient between regions j and h, and D_{jh} for the relative degree of women's development between regions j and h(h). D_{jh} represents the degree of impact of the contribution rate of WDI between the j(h) areas; d represents the difference in the contribution rate of WDI between regions; and p_{jh} represents the hypervariance first-order matrix.

2.4. Data Sources

The China Statistical Yearbook for the Regional Economy and the China Statistical Yearbook on the Environment provide information on the indicators used for this study, including the per capita water supply, urban built-up area, wastewater emissions, industrial waste gas emissions, and general solid waste emissions. The IPCC subsectoral technique was used to calculate the carbon emissions statistics, which were taken from the China Carbon Accounting Database. The information on the subsectors of the HI, EI, and income index was gathered from the China Population & Employment Statistical Yearbook, China Health Statistical Yearbook, China Health and Family Planning Statistical Yearbook, and the Statistical Yearbooks of each province. The China General Social Survey covers all provinces and regions in China and includes micro-research data from five provinces in Northwest China, and the first survey was carried out in 2003. The starting year of this study was 2003 for the convenience of calculating the comprehensive well-being of women in Northwest China at a later stage. The ranges of average life expectancy, average years of education, and per capita disposable income indicators were derived from the Human Development Report (2019). The minimum values of maternal mortality, the detection rate of women's diseases, the illiteracy rate of women over 15 years old, the proportion of women among university students, the employment rate of urban women in other units, women's unemployment rate, resource consumption, and pollution emissions were set to 0, and the maximum values were set to the maximum values not reached in each province. Due to the absence of carbon emission data for 2020 and wastewater emission data for 2018–2020 in the statistical yearbook and the fact that the growth rates of these two sets of data have changed little in the last five years, the average growth rates of previous years were used to estimate the value. There was a change in the statistical caliber of solid waste in 2011, so the maximum value was set in segments.

3. Results

3.1. Spatial and Temporal Changes in the Level of Women's Development in Northwest China

We measured the level of women's development in Northwest China using the algorithm of the WDI under the influence of ecological factors, analyzed its spatial and temporal-change characteristics, and classified the WDI into low, medium, and high levels. The years 2003, 2012, and 2020 were chosen as research-time nodes, and the ArcGIS software was used to visualize and express the level of women's development in Northwest China. The HDI for women in Northwest China was chosen as the control group to which to compare the effects of each element on the degree of the development of women.

3.1.1. Time Variation

From observing the WDI in Northwest China under the influence of ecological factors (Table 3, Figure 4, first row), the overall trend of WDI in Northwest China from 2003 to 2020 increased from 0.525 in 2003 to 0.629 in 2012, showing an increase of 0.105 (19.95%), and by

a further 0.061 from 2012 to 2020, an increase of 9.61%. The degree of variation between provinces shows a trend of first increasing and then decreasing, with the range and standard deviation increasing from 0.163 and 0.058 in 2003 to 0.134 and 0.046 in 2012 and to 0.147 and 0.050 in 2020, respectively, and the year with the largest range and standard deviation was 2016, with values of 0.181 and 0.058, respectively. Due to ecological considerations, the provinces showed the largest difference of WDI in 2016. In contrast to Qinghai, where WDI's level were at their lowest in 2003, and Ningxia, where they were at their lowest in 2020, the WDI values were maintained at a reasonably high level in Shaanxi Province and rose consistently. With the exception of Ningxia, the lowest value in every province was recorded in 2003, the highest value in Shaanxi, Qinghai, and Xinjiang was recorded in 2020, and the highest value in Gansu and Ningxia was recorded in 2016.

Looking at the women's HDI in Northwest China (Table 4, Figure 4, second row), the overall trend uniformly increased between 2003 and 2020 from 0.554 in 2003 to 0.650 in 2012, with an increase of 0.096 (17.34%), and further increased by 0.059 (9.08%) from 2012 to 2020. The degree of difference between provinces showed a trend of first expanding and then decreasing, with the range and standard deviation increasing from 0.059 and 0.024 in 2003 to 0.065 and 0.024 in 2012, and to 0.078 and 0.028 in 2015, and then decreasing to 0.058 and 0.022 in 2020, with the greatest difference in the HDI among women in each province in 2015. In all 5 Northwest Chinese provinces, there was a consistent upward trend in the degree of women's well-being. Among them, the province of Shaanxi consistently maintained a high degree of well-being throughout the years. Both Gansu and Qinghai had lower well-being ratings in 2003, while Qinghai had the lowest level in 2020. In each province, the women's HDI score peaked in 2020 after reaching its maximum point in 2003.

Table 3. Effects of Ecological Factors on WDI in Northwest China from 2003 to 2020.

Year	SX	GS	QH	NX	XJ	Standard Deviation	Range	NC
2003	0.605	0.510	0.442	0.575	0.492	0.058	0.163	0.525
2004	0.602	0.517	0.475	0.584	0.532	0.046	0.126	0.542
2005	0.607	0.492	0.474	0.507	0.530	0.046	0.133	0.522
2006	0.633	0.512	0.515	0.575	0.551	0.045	0.121	0.557
2007	0.642	0.541	0.536	0.541	0.577	0.040	0.106	0.567
2008	0.665	0.570	0.551	0.568	0.594	0.040	0.114	0.589
2009	0.676	0.574	0.578	0.557	0.636	0.045	0.119	0.604
2010	0.696	0.611	0.583	0.545	0.618	0.050	0.151	0.611
2011	0.709	0.606	0.598	0.603	0.639	0.042	0.111	0.631
2003–2012	0.110	0.114	0.160	0.049	0.090	0.036	0.112	0.105
2012	0.716	0.623	0.603	0.623	0.582	0.046	0.134	0.629
2013	0.734	0.645	0.607	0.655	0.596	0.049	0.138	0.648
2014	0.729	0.658	0.640	0.638	0.630	0.036	0.099	0.659
2015	0.750	0.658	0.599	0.660	0.639	0.050	0.151	0.661
2016	0.759	0.679	0.578	0.670	0.659	0.058	0.181	0.669
2017	0.765	0.679	0.633	0.653	0.681	0.045	0.132	0.682
2018	0.764	0.652	0.651	0.622	0.687	0.049	0.142	0.675
2019	0.771	0.664	0.650	0.592	0.688	0.058	0.179	0.673
2020	0.780	0.676	0.661	0.633	0.700	0.050	0.147	0.690
2012–2020	0.065	0.052	0.058	0.010	0.118	0.034	0.108	0.061

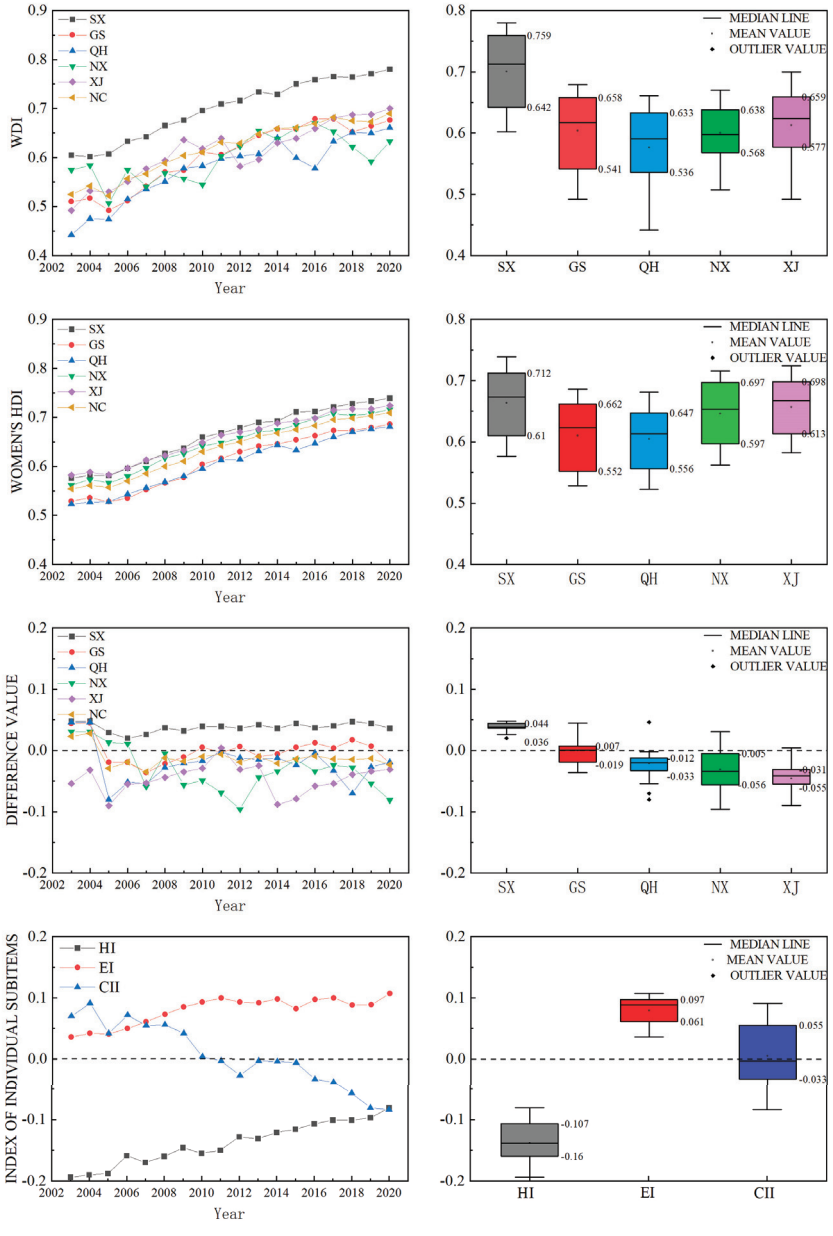


Figure 4. Temporal Changes in WDI and Women's HDI, and the Difference Between Them in Northwest China and in the 5 Provinces from 2003 to 2020.

Table 4. Women's HDI in Northwest China from 2003 to 2020.

	SX	GS	QH	NX	XJ	Standard Deviation	Range	NC
2003	0.576	0.529	0.523	0.562	0.582	0.024	0.059	0.554
2004	0.582	0.536	0.527	0.573	0.588	0.025	0.061	0.561
2005	0.581	0.528	0.528	0.566	0.583	0.025	0.056	0.557
2006	0.596	0.535	0.543	0.580	0.596	0.026	0.061	0.570
2007	0.610	0.552	0.556	0.597	0.613	0.026	0.061	0.585
2008	0.626	0.566	0.568	0.617	0.622	0.027	0.060	0.600
2009	0.637	0.577	0.580	0.626	0.633	0.026	0.059	0.610
2010	0.660	0.604	0.595	0.642	0.649	0.026	0.065	0.630
2011	0.668	0.616	0.613	0.648	0.664	0.023	0.055	0.642
2003–2012	0.103	0.101	0.092	0.096	0.088	0.005	0.015	0.096
2012	0.679	0.630	0.614	0.658	0.670	0.024	0.065	0.650
2013	0.690	0.641	0.631	0.671	0.676	0.022	0.060	0.662
2014	0.692	0.646	0.644	0.673	0.688	0.020	0.048	0.668
2015	0.711	0.654	0.633	0.685	0.693	0.028	0.078	0.675
2016	0.712	0.662	0.647	0.697	0.698	0.024	0.064	0.683
2017	0.721	0.673	0.660	0.708	0.715	0.024	0.061	0.695
2018	0.728	0.673	0.670	0.703	0.717	0.023	0.058	0.698
2019	0.733	0.679	0.676	0.708	0.717	0.022	0.057	0.703
2020	0.739	0.686	0.681	0.716	0.724	0.022	0.058	0.709
2012–2020	0.060	0.057	0.066	0.058	0.054	0.004	0.012	0.059

Women's HDI and each subitem were deducted from the WDI and from the health, education, and income subitems in each province from 2003 to 2020 to more thoroughly examine the impact of each aspect of the WDI under the influence of ecological variables in Northwest China. The findings are displayed in the third and fourth row plots of Figure 4. While Shaanxi's WDI was higher than the women's HDI level from the point of view of each province, Qinghai and Xinjiang's WDI continued to be below the women's HDI level, and Gansu and Ningxia's WDI were typically lower than the women's HDI. The overall level of WDI in Northwest China was lower than the level of women's HDI. The EI level in the WDI was consistently lower than the education subindex of the HDI for women in terms of the differences in health, education, and income because maternal mortality and the rate of gynecological disease detection lowered the level of the index measured using only female life expectancy. Although the level of the EI in the WDI was initially greater than the EI of the female HDI, the addition of the factors, percentage of female college students and the illiteracy rate of women over 15 years old, to the development index raised the level of the index, calculated using only years of schooling, and made the measurement more accurate. The CII in WDI subcomponent fluctuated slightly, and its indicator layer showed slower changes in X4, X5, and X6, which made the EII the main determinant of the difference in the CII. According to comparative analysis and differential research, the growth in RCI and PEI had a significant impact on each province's WDI, while the women's HDI disregarded the importance of ecological factors and did not properly gauge women's well-being levels. As a result, the variations in the degree of women's well-being in each province in Northwest China may be better described by the WDI in each area under the effect of ecological variables.

3.1.2. Spatial Variation

In terms of the WDI in Northwest China under the influence of ecological factors, except for Shaanxi, which reached a medium level of WDI in 2003, the other four provinces were at the low level, while in 2012, Gansu, Ningxia, and Qinghai reached the medium level of WDI, Xinjiang was still at the low level, and Shaanxi improved to a high level and reached the overall WDI in Northwest China. By 2020, Xinjiang had surpassed Qinghai, Gansu, and Ningxia in terms of WDI.

The women's HDI in all of the provinces in Northwest China tended to increase. Northwest China had a low level of HDI overall in 2003; by 2012, all of its provinces had achieved a medium level; and by 2020, all provinces in the area had attained a high level of development, with the exception of Gansu, and Qinghai maintained a medium level (Figure 5).

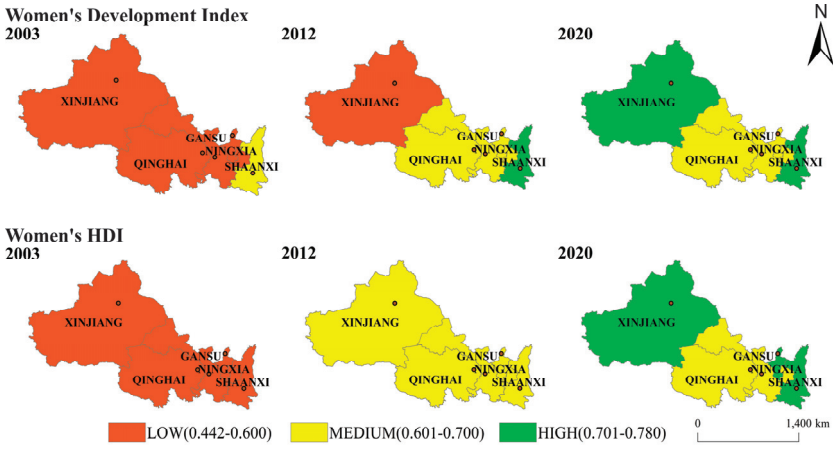


Figure 5. Comparison of WDI and Women's HDI in Northwest China in Space Variation.

We discovered that ecological variables had a significant impact on the level of WDI in Northwest China by comparing and evaluating the WDI in Northwest China under the influence of ecological factors with the women's HDI in each province. With the inclusion of ecological elements, the total WDI in Northwest China varied significantly, and there were significant variations across provinces. Due to its low EII values for resource consumption and pollution emissions, Shaanxi was the only one of the provinces to attain a medium level of development in 2003. By 2011, it had become the only high-level province among the five northwest Chinese provinces. As a result of higher values of RCI and PEI in the EII, Gansu, Qinghai, and Ningxia fell behind other provinces in terms of WDI, while Xinjiang maintained its low level of WDI in 2012 and advanced to a high level in 2020 as a result of a high value of EII from 2003 to 2012 and a considerable drop in the EII from 2012 to 2020. Income level was the primary factor impacting the unequal level of well-being among provinces, along with the environmental effect factor.

3.2. Analysis of the Spatial Imbalance of Women's Well-Being in Northwest China

3.2.1. Imbalance Analysis of the WDI and CII Based on the Theil Index

The degree of regional well-being is significantly influenced by the income element. In this subsection, we utilized the Theil index to examine the degree of imbalance and changes in the WDI and CII across Northwest China and the 5 provinces under the impact of EII. Figure 6 compares the degrees of WDI imbalance and CII imbalance for Northwest China and the five provinces, and their cumulative WDI and CII imbalances under the Theil index, from 2003 to 2020.

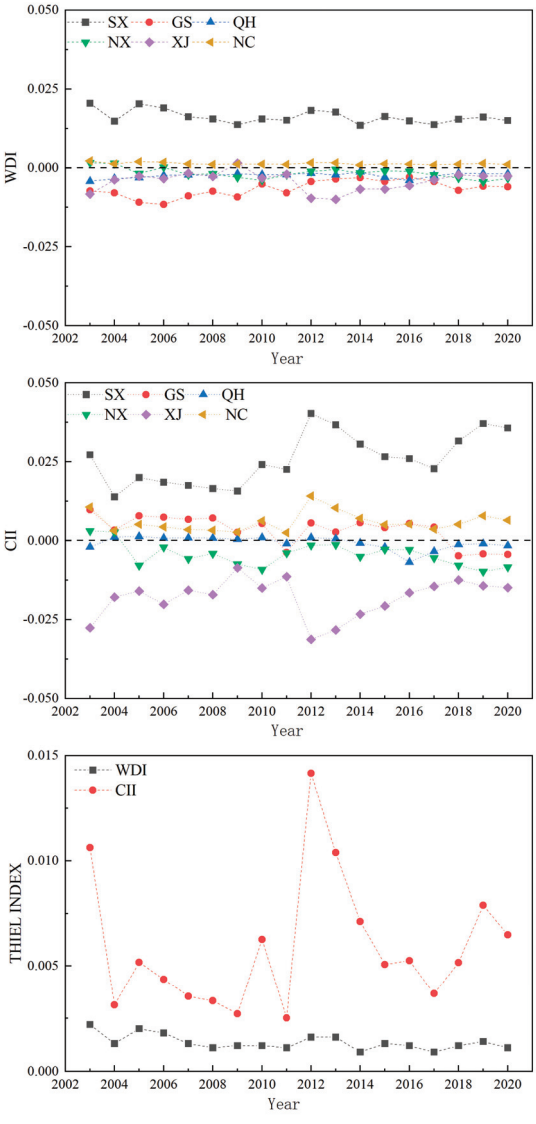


Figure 6. The Degree of Inequality in the Development and Income Indices of Northwest China and the Five Provinces According to the Theil Index from 2003 to 2020.

The degree of change in the WDI and the fluctuation range was noticeably smaller than that of the CII, and the imbalance level of the WDI and CII in Shaanxi was higher than the overall level of Northwest China according to the changes in the imbalance of WDI and CII across the provinces. In terms of the degree of WDI imbalance, Shaanxi had the highest value, peaking at 0.0182 in 2012, while Gansu, Qinghai, and Xinjiang maintained negative values. Xinjiang had the lowest value, and its imbalance value stayed negative from 2003 to 2020, falling to its lowest value of -0.0313 in 2012. Shaanxi still had reached the highest value among the five provinces in terms of income level imbalance, climbing to the maximum value of 0.0403 in 2012.

The Theil index was used to compare the WDI and CII of Northwest China in terms of the environmental effect, and the results reveal that both of these indices trended up

and then down from 2003 to 2020, with the WDI being much lower than the CII. The CII fluctuated, increasing from 2003 to 2012 and peaking at 0.0142 in 2012, which demonstrated that the disparity in female income level reached its highest under the effect of ecological variables in Northwest China. The index then steadily declined with fluctuations, reaching 0.0065 in 2020, which was lower than the value of 0.0106 in 2003. The greatest value of 0.0016 was recorded in 2012, indicating a more moderate overall shift in the degree of imbalance. Fewer value changes occurred from 2003 to 2020, changing from 0.0022 to 0.0011.

The Theil index was used to analyze the disparity between the WDI and the CII in Northwest China. The results revealed that, while there were ups and downs in all provinces, the degree of imbalance tended to stabilize. The degree of CII disparity was much larger than the degree of WDI disparity. The year with the greatest income level disparity between regions as a result of WDI and ecological variables was 2012.

3.2.2. Gap Analysis of WDI Based on the Dagum Gini Coefficient

Table 5 illustrates the extent and trend of interregional variations in WDI under the effect of ecological variables among the five provinces in Northwest China. Overall, there was a decreasing tendency in the interprovincial gap between provinces, with the highest interprovincial gap between provinces occurring in 2003 and the smallest interprovincial gap occurring in 2014. The largest difference between provinces was found between Shaanxi and Qinghai in 2003, while the smallest difference was found between Gansu and Qinghai in 2018.

Table 5. Interregional Gini coefficient of the WDI of Five Provinces in Northwest China from 2003 to 2020.

Year	Overall G	(G-S)	(Q-S)	(Q-G)	(N-S)	(N-G)	(N-Q)	(X-S)	(X-G)	(X-Q)	(X-N)
2003	0.0623	0.0859	0.1555	0.0706	0.0261	0.0599	0.1299	0.1036	0.0179	0.0528	0.0777
2004	0.0471	0.0754	0.1174	0.0423	0.0152	0.0603	0.1023	0.0611	0.0144	0.0567	0.0459
2005	0.0466	0.1043	0.1231	0.0190	0.0891	0.0153	0.0344	0.0675	0.0370	0.0560	0.0217
2006	0.0434	0.1056	0.1030	0.0026	0.0475	0.0583	0.0558	0.0690	0.0368	0.0343	0.0215
2007	0.0351	0.0853	0.0903	0.0050	0.0854	0.0001	0.0049	0.0529	0.0326	0.0375	0.0326
2008	0.0345	0.0766	0.0939	0.0174	0.0786	0.0020	0.0154	0.0567	0.0200	0.0374	0.0220
2009	0.0397	0.0813	0.0781	0.0032	0.0965	0.0154	0.0186	0.0301	0.0513	0.0481	0.0666
2010	0.0443	0.0657	0.0890	0.0234	0.1218	0.0565	0.0332	0.0594	0.0063	0.0297	0.0628
2011	0.0328	0.0786	0.0851	0.0066	0.0807	0.0022	0.0044	0.0521	0.0267	0.0332	0.0288
2012	0.0366	0.0688	0.0854	0.0168	0.0689	0.0001	0.0167	0.1029	0.0344	0.0176	0.0343
2013	0.0401	0.0645	0.0951	0.0308	0.0568	0.0077	0.0385	0.1037	0.0395	0.0086	0.0471
2014	0.0264	0.0518	0.0655	0.0137	0.0666	0.0148	0.0011	0.0731	0.0213	0.0076	0.0065
2015	0.0391	0.0654	0.1119	0.0469	0.0640	0.0014	0.0483	0.0800	0.0147	0.0322	0.0161
2016	0.0457	0.0550	0.1353	0.0809	0.0623	0.0073	0.0736	0.0704	0.0154	0.0656	0.0081
2017	0.0341	0.0592	0.0941	0.0351	0.0786	0.0195	0.0156	0.0579	0.0013	0.0364	0.0208
2018	0.0379	0.0790	0.0796	0.0006	0.1026	0.0239	0.0233	0.0533	0.0258	0.0264	0.0497
2019	0.0470	0.0745	0.0848	0.0103	0.1314	0.0575	0.0472	0.0570	0.0176	0.0279	0.0750
2020	0.0386	0.0719	0.0829	0.0111	0.1038	0.0321	0.0210	0.0542	0.0178	0.0289	0.0499

When comparing the 10 pairs of provinces, the disparity in WDI between Shaanxi and the other four was more than the gap in development between other provinces, although the distance between Gansu, Qinghai, and the other three provinces, except for Shaanxi, was smaller. Between 2003 and 2020, there was progressively less variation in the distance between Xinjiang and the other four provinces, and all of the gap levels were lower in 2020 than in 2003.

The total Dagum Gini coefficient for Northwest China decreased continuously from 2003 to 2008 and then fluctuated gradually from 2008 to 2020, with the lowest value of 0.0345 occurring in 2008 and the greatest value of 0.0457 occurring in 2016. The Gini coefficient decreased by 38.09%, from 0.0623 in 2003 to 0.0386 in 2020. After 2010, the Gini

coefficient maintained a consistent value of 0.04. This shows that the variation in the WDI gap among the five provinces, as affected by ecological factors, was steadily decreasing.

4. Discussion

Women's well-being has developed into a significant study issue in geography and sociology as a group-research component of well-being research [73,74]. Creating an index system, is a typical mathematical technique to assess the level of regional growth and well-being. Ecological elements, nevertheless, were not always seen to be sufficient for the well-being of local women. The HDI's three-dimensional measures of health, education, and income were used in this essay. This study created the Northwest WDI to assess the degree of regional women's well-being by enriching the index layers of health, education, and income index and incorporating the environmental impact component as the cost consumption of social production into the income index dimension. Due to the large proportion of industrial production among the three industries in the study area, industrial production has the highest contribution value to regional development. However, due to the extensive social-production mode, serious resource consumption, and pollution emission, the regional development is restricted [62,63]. Therefore, the change in production level in this area can be reflected by the change in the environmental impact factor, which adds a scientific component to the evaluation of environmental impact factors in the income index dimension. As the HDI faces the problem of having too few indicators, this article focused on enhancing the indicators of health, education, and income to prevent limitations from determining the degree of regional development based only on the three positive indicators of life expectancy, average years of schooling, and income level. It also performed a comparison analysis and difference calculation between the study findings and the results of the HDI. Hence, the calculation results better reflect the differences between the method constructed in this paper and the HDI, and measure the regional WDI in a more scientific and comprehensive way. This research provides a way to measure regional levels of women's well-being. When measuring the WDI Northwest China, this paper considers not only the changes in time but also the changes in space, which can more intuitively reveal the differences in regional WDI. Moreover, the index method in this research is unique and regionally applicable. Since all of the variables chosen were the most significant to women's growth in Northwest China, the index system described in this work is appropriate for measuring women's development in areas with fragile and extensive ecological production and regressive female education, income, and health.

Regional-development inequalities, imbalanced circumstances, and regional geographic polarization are frequently related to regional development. This paper employed a measurement method widely used in the School of Economics to calculate the WDI in Northwest China, as well as the Theil Index to calculate unbalanced development in Northwest China, analyzing the development gap between the five provinces and regions using the Dagum Gini coefficient [64,71]. The development gap between provinces in Northwest China is enormous, which will make it impossible to realize the region's overall growth if the regional imbalance is not adjusted. It is beneficial to further increase the well-being level of women in Northwest China by measuring regional inequalities and changes in Northwest China's well-being. The ratio found in earlier research was used to choose the women's calculation RCI and the PEI in Northwest China for this study. The annual per capita water consumption of women was 10% higher than that of men [75], the gender ratio in China had a 1% influence on pollutant emissions, and the higher the gender ratio is, the higher the emissions of pollutants [76]. The carbon dioxide emissions in China increased by 1.394% for every unit increase in the gender ratio [77]. In this study, the model was slightly modified to calculate the per capita emissions of the Northwest China when the sex ratio is 100 because previous calculations of pollution emissions using the ratio of CO_2 emissions result in positive emissions for men and negative emissions for women, which is not consistent with the actual situation. In contrast, no quantitative research has been undertaken regarding the built-up area per capita for urban women,

which was determined by taking into account the total number of urban households, the urban sex ratio, and the typical number of urban family members per household.

We looked for plausible explanations for the temporal and geographic variability in WDI across Northwest China. Overall, regional development is greatly influenced by how national policies and initiatives were carried out. The State Council of China issued the Notice on Policies and Measures for the Implementation of the Large-Scale Development of the Western Region on 26 October 2000. The 11th Five-Year Plan for the Large-scale Development of the Western Region was implemented in 2006, and the 12th Five-Year Plan for the Large-scale Development of the Western Region was implemented in 2012. In general, the western area has begun and expedited the development of infrastructure, the natural environment, research, technology, and education. The capital demand of the development of northwest China was safeguarded through national debt investment. Highway Construction of major national highways was accelerated. They made steady progress in converting farming to forest and grassland, as well as in afforestation and grass-planting on barren slopes and wastelands from an ecological standpoint. China put forward the "Belt and Road" Initiative in 2013. "The Belt and Road" (B&R) is short for "Silk Road Economic Belt" and "21st Century Maritime Silk Road". Its economic meaning was of vital importance. Northwest China held the following position: It would serve as a commerce and logistics center, an important industry, and as a basis for cultural interchange for nations in Central, South, and West Asia, which had given the region's economic growth new life. The health of women in Northwest China is gradually increasing, according to the HI. The relevance of physical exams for women and expectant mothers was steadily increased throughout all provinces and regions, as was the standard of women's medical security. The Shaanxi Women's Health Promotion Program and other provincial initiatives sought to increase the health of women while lowering the death rates for breast and cervix cancer. The major strategy was to encourage young women to take advantage of free gynecological exams. The project had a 5-year cycle, and the target population's examination coverage rate was capable of exceeding 80% to 85%. In locations where the circumstances allow, this rate may be steadily increased. Over 90% of cervical cancer cases were detected early. More than 95% of aberrant or suspicious cases were managed in the following manner. The capacity of the women's health services had increased, and over 95% of the inspectors in the project regions had received training. As a consequence, from 2003 to 2020, the women's health index had grown annually.

According to the II, the growth of the secondary and tertiary sectors heavily influences the production mode of the five provinces. According to this analysis, between 2003 and 2020, women's per capita disposable income increased along with the growth of the GDP. The government helped women launch enterprises and get jobs from the standpoint of female employment. It decided to use strategies such as providing women with small, guaranteed loans, teaching them labor-market skills, building up demonstration bases for reducing women's poverty, and providing impoverished women with breeding and planting facilities. Online e-commerce and Internet Plus have increased local women's job opportunities in recent years thanks to the advancement of Internet technology. In Northwest China, women were increasingly choosing a job outside of the government system.

RCI and PEI were the key determinants of CII. From 2009 to 2016, the largest concentrations of resource use and environmental emissions occurred in Qinghai, Ningxia, and Xinjiang. The primary industrial sectors in Qinghai, Ningxia, and Xinjiang were non-ferrous metal smelting and rolling processing industry, electricity and heat production and supply, and oil and gas exploitation. The industrial products in these regions were mostly natural crude oil, natural gas, and raw salt. The objective of regional development has changed from raising GDP to conserving regional ecology with a focus on the conservation of the ecological environment in western China. The government has started to limit the growth of industries with high pollution and high consumption, to introduce green production technology, promote regional ecological development beforehand, promote regional industrial transformation, and upgrade in order to create a strong national ecological security

barrier. RCI and PEI have thus gradually decreased in the provinces of Northwest China in recent years. In WDI, there was a significant disparity between the provinces, and the overall trend was upward. The guarantee of educational funds and the system of awards and subsidies for operating schools in other places have been continuously improved, the safety projects and standardization construction of primary and secondary schools have been gradually completed, and the conditions for operating schools had been significantly improved, according to the EI. During the nation's drive to combat poverty, the China Women's Federation and other groups actively encouraged literacy in rural regions. The percentage of illiterate women has been falling annually, and all pupils received better educations with time. In order to increase the number of women who can attend college, we would encourage the building of colleges and institutions in the western area. Therefore, the women's EI increased year by year from 2003 to 2020.

At present, studies on regional women's well-being often focus on the exploration of factors affecting women's well-being and life satisfaction. However, there are few studies on the spatial and temporal changes in regional women's well-being in a macro-sense. The key to improving women's well-being in Northwest China and reducing the imbalance of women's well-being among regions is to protect the local ecology, improve the local economy, and realize the balance of well-being among regions by means of component complementarity. Based on the analysis of the current situation of women's development in Northwest China and the actual situation of politics, social economy and education in each province, the following suggestions are put forward from the perspectives of ecology, health, education, and income from different subjects such as government, society and family:

1. Protecting the local environment, modernizing and restructuring the industrial structure, switching the regional development model, and raising the regional development level are the essential steps that need to be taken to increase the well-being of women in Northwest China. By utilizing national strategic initiatives such as the Great Western Development and the Silk Road to jump onto the new era's wave of fast development, we will cut resource consumption and pollution emissions. We also plan to bring sophisticated science and technology as well as green and energy-saving businesses, and to encourage the growth of regional traditions, distinctive landforms, and a sense of place.
2. By implementing a systematic and effective gender budgeting system and other measures, the nation will update the social security funding model, raise social security spending, and create a social security system with the overarching objective of achieving gender equality and ending gender segregation. We will strengthen the protections offered to women in the areas of unemployment insurance, health insurance, maternity insurance, old age insurance, and medical insurance.
3. Education is a critical tool for women seeking equality and advancement. A woman's knowledge of the world and level of professional engagement in social activities are both influenced by their degree of education. In addition to the fundamental requirement that women in Northwest China have equal access to education, it is important to encourage women to pursue higher education and to increase their general awareness through financial aid and increased enrollment quotas. However, women might earn more money in line with their degree of education after completing a higher education.
4. When women work in the social sphere, they may convert the labor force that has been primarily focused on the home sphere into economic revenue, which can raise individual income levels and strengthen family relationships. The expansion of women's employment sectors, the addition of women's employment positions, the reasonable arrangement of employment training, the optimization of women's employment structures, the promotion of women's employment level, and the improvement of women's employment quality can all be done against the background of the growing

proportion of tourism and other tertiary industries in the ecologically vulnerable provinces of Northwest China.

This article still has some limitations. There may be some discrepancies between the measurement results and the actual situation as a result of the lack of specific male and female resource consumption and pollution-emission ratio data in the calculation of the index system. We acknowledge that the use of the EII in this study does have some limits. The data on women's ecological input in Northwest China were scarce, and data collection was challenging due to the broad measurement area and the lengthy time series. Furthermore, resource consumption and pollutant emissions have a significant influence on regional development in Northwest China due to its delicate natural environment. Some scholars [67,75] have studied the resource consumption and pollution emissions caused by gender differences in the past, so the indicators in this study can reflect the impact of EII on regional female development to a certain extent. The six EII variables were taken into account in this study's income subcategory as a cost and loss to social production utilizing Atkinson's inequality assessment approach. They were the temporary alternative indicators that we used to assess the influence of ecological variables on the development of women. Future small-scale regional study may use questionnaires and other tools to gather more pertinent data. In the future, more precise objective indicators will be chosen and calculated. To examine the gender disparity in well-being, the region's male and female well-being indicators will be chosen. This measurement encompasses a large and extensive area, and it lacks microdata on a micro scale; therefore, its practical reference relevance for the growth of different provinces and regions is unclear. The sole objective well-being of female groups in Northwest China is the focus of this measurement. The data collected from the China General Social Survey and China Family Tracking Survey will be used in future research to improve the comprehensive measurement of women's well-being in Northwest China and provide a more proper examination of women's well-being in the area.

5. Conclusions

To explore the degree of spatial inequality and changes in women's well-being under the effect of ecological factors in Northwest China, this article considered women from five provinces as the research subject. The Theil index and Dagum Gini coefficient were then used to examine the data to build an index of the development of women in Northwest China under the effect of ecological variables. The conclusions are as follows.

From the temporal perspective, the overall trend of women's well-being measured by WDI under the influence of ecological factors increased from 2003 to 2020 in Northwest China, with the exception of Shaanxi. The other four provinces had fluctuating changes, and the addition of ecological factors increased the fluctuation degree of WDI in Northwest China, which was more suitable for the actual situation. The addition of other indicators in the education, health, and income indices made the well-being measurement more comprehensive and scientific.

From the spatial perspective, the degree of variation in women's well-being among the five provinces of the Northwest China WDI was stronger than that of the HDI. Among the five provinces, Shaanxi Province maintained the highest level of women's development, and in 2012, Shaanxi was the only province and region with a high level of WDI, while Xinjiang had the greatest change in development, rapidly improving from a low level of WDI in 2012 to a high level of WDI in 2020.

Among in the five provinces in Northwest China, the women's well-being's imbalance between WDI and CII from 2003 to 2020 was the largest in Shaanxi and the smallest in Xinjiang, while the imbalance between WDI and CII in Qinghai and Ningxia was relatively stable, and the level of imbalance in each province and region gradually decreased and stabilized during the fluctuations. In the future, the unbalanced development in Northwest China will show a decreasing trend, and the difference in WDI will be lower than the CII.

The gap in women's well-being as calculated by WDI under the influence of ecological factors among 10 pairs of provinces in Northwest China from 2003 to 2020 showed a decreasing trend with fluctuations. The gap between Shaanxi and the remaining four provinces in terms of WDI was relatively large, and the gap in WDI in Gansu, Qinghai and the remaining three provinces was smaller. The overall Dagum Gini coefficient gradually stabilized at approximately 0.04.

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References

1. Huang, G.; Jiang, Y.; Liu, Z.; Nie, M.; Liu, Y.; Li, J.; Bao, Y.; Wang, Y.; Wu, J. Advances in human well-being research: A sustainability science perspective. *Acta Ecol. Sin.* **2016**, *36*, 7519–7527.
2. Li, Q.; Chen, H. The Relationship between Human Well-Being and Carbon Emissions. *Sustainability* **2021**, *13*, 547. [CrossRef]
3. Ray, A.K. Measurement of social development: An international comparison. *Soc. Indic. Res.* **2008**, *86*, 1–46. [CrossRef]
4. Mirahmadizadeh, A.; Ghelichi-Ghojogh, M.; Vali, M.; Jokari, K.; Ghaem, H.; Hemmati, A.; Jafari, F.; Dehghani, S.S.; Hassani, A.H.; Jafari, A.; et al. Correlation between human development index and its components with COVID–19 indices: A global level ecologic study. *BMC Public Health* **2022**, *22*, 1. [CrossRef]
5. Zhai, C.; Wang, S. Spatio-temporal difference evolution and scenario simulation of multi-dimensional well-being in Poyang Lake area based on system dynamics. *Acta Ecol. Sin.* **2021**, *41*, 2954–2967.
6. Nugroho, T.W.; Hanani, N.; Toiba, H.; Sujarwo, S. Promoting Subjective Well-Being among Rural and Urban Residents in Indonesia: Does Social Capital Matter? *Sustainability* **2022**, *14*, 4.
7. Rahman, M.S.; Andriatmoko, N.D.; Saeri, M.; Subagio, H.; Malik, A.; Triastono, J.; Oelviani, R.; Kilmanun, J.C.; da Silva, H.; Pesireron, M.; et al. Climate Disasters and Subjective Well-Being among Urban and Rural Residents in Indonesia. *Sustainability* **2022**, *14*, 6.
8. Song, M.; Huntsinger, L.; Han, M. How does the Ecological Well-Being of Urban and Rural Residents Change with Rural-Urban Land Conversion? The Case of Hubei, China. *Sustainability* **2018**, *10*, 2.
9. Women's Well-Being Index. Available online: https://calbudgetcenter.org/resources/womens-well-being-index/ (accessed on 12 December 2022).
10. Gender Disparity Index. Available online: https://womenandprogress.org/ (accessed on 12 December 2022).
11. Belmin, C.; Hoffmann, R.; Elkasabi, M.; Pichler, P. LivWell: A sub-national dataset on the living conditions of women and their well-being for 52 countries. *Sci. Data* **2022**, *9*, 719. [CrossRef] [PubMed]
12. Panday, P. Women's Empowerment and the Well-being of Children in Nepal. *J. Dev. Soc.* **2020**, *36*, 129–154.
13. Roseboom, T.J. Why achieving gender equality is of fundamental importance to improve the health and well-being of future generations: A DOHaD perspective. *J. Dev. Orig. Health Dis.* **2020**, *11*, 101–104. [CrossRef]
14. Chen, F.; Bao, L.; Shattuck, R.M.; Borja, J.B.; Gultiano, S. Implications of Changes in Family Structure and Composition for the Psychological Well-Being of Filipino Women in Middle and Later Years. *Res. Aging* **2017**, *39*, 275–299. [CrossRef]
15. Strange, J.M. In Full Possession of Her Powers: Researching and Rethinking Menopause in early Twentieth-century England and Scotland. *Soc. Hist. Med.* **2012**, *25*, 685–700. [CrossRef]
16. Schulte, P.; Vainio, H. Well-being at work—Overview and perspective. *Scand. J. Work Environ. Health* **2010**, *36*, 422–429. [CrossRef]
17. Gilbert-Ouimet, M.; Brisson, C.; Vezina, M. Psychosocial work stressors, high family responsibilities, and psychological distress among women: A 5-year prospective study. *Am. J. Ind. Med.* **2020**, *63*, 170–179. [CrossRef]
18. Gur, R.E.; White, L.K.; Waller, R.; Barzilay, R.; Moore, T.M.; Kornfield, S.; Njoroge, W.F.M.; Duncan, A.F.; Chaiyachati, B.H.; Parish-Morris, J.; et al. The Disproportionate Burden of the COVID–19 Pandemic Among Pregnant Black Women. *Psychiatry Res.* **2020**, *293*, 113475. [CrossRef]

19. Padrosa, E.; Vanroelen, C.; Muntaner, C.; Benach, J.; Julia, M. Precarious employment and mental health across European welfare states: A gender perspective. *Int. Arch. Occup. Environ. Health* **2022**, *95*, 1463–1480. [CrossRef]
20. Pitchforth, J.; Fahy, K.; Ford, T.; Wolpert, M.; Viner, R.M.; Hargreaves, D.S. Mental health and well-being trends among children and young people in the UK, 1995–2014: Analysis of repeated cross-sectional national health surveys. *Psychol. Med.* **2019**, *49*, 1275–1285. [CrossRef]
21. Damaske, S.; Bratter, J.L.; Frech, A. Single mother families and employment, race, and poverty in changing economic times. *Soc. Sci. Res.* **2017**, *62*, 120–133. [CrossRef] [PubMed]
22. Trzcinski, E.; Holst, E. Gender Differences in Subjective Well-Being in and out of Management Positions. *Soc. Indic. Res.* **2012**, *107*, 449–463. [CrossRef]
23. Emerson, E.; Hatton, C. Self-reported well-being of women and men with intellectual disabilities in England. *Am. J. Ment. Retard.* **2008**, *113*, 143–155. [CrossRef] [PubMed]
24. Torchio, M.F.; Lucia, U.; Grisolia, G. Economic and Human Features for Energy and Environmental Indicators: A Tool to Assess Countries' Progress towards Sustainability. *Sustainability* **2020**, *12*, 9716. [CrossRef]
25. Ture, C.; Ture, Y. A model for the sustainability assessment based on the human development index in districts of Megacity Istanbul (Turkey). *Environ. Dev. Sustain.* **2021**, *23*, 3623–3637. [CrossRef]
26. Biggs, R.; Clements, H.S.; Cumming, G.S.; Cundill, G.; de Vos, A.; Hamann, M.; Luvuno, L.; Roux, D.J.; Selomane, O.; Blanchard, R.; et al. Social-ecological change: Insights from the Southern African Program on Ecosystem Change and Society. *Ecosyst. People* **2022**, *18*, 447–468. [CrossRef]
27. Pereira, E.; Queiroz, C.; Pereira, H.M.; Vicente, L. Ecosystem services and human well-being: A participatory study in a mountain community in Portugal. *Ecol. Soc.* **2005**, *10*, 2. [CrossRef]
28. Smith, L.M.; Case, J.L.; Smith, H.M.; Harwell, L.C.; Summers, J.K. Relating ecoystem services to domains of human well-being: Foundation for a US index. *Ecol. Indic.* **2013**, *28*, 79–90. [CrossRef]
29. Yang, J.; Ma, X.; Zhao, X.; Li, W. Spatiotemporal of the Coupling Relationship between Ecosystem Services and Human Well-Being in Guanzhong Plain Urban Agglomeration. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12535. [CrossRef]
30. Yee, S.H. Contributions of Ecosystem Services to Human Well-Being in Puerto Rico. *Sustainability* **2020**, *12*, 9625. [CrossRef]
31. Heywood, I.; Sammut, D.; Bradbury-Jones, C. A qualitative exploration of 'thrivership' among women who have experienced domestic violence and abuse: Development of a new model. *BMC Womens Health* **2019**, *19*, 1. [CrossRef]
32. Bell, R.J.; Donath, S.; Davison, S.L.; Davis, S.R. Endogenous androgen levels and well-being: Differences between premenopausal and postmenopausal women. *Menopause-J. N. Am. Menopause Soc.* **2006**, *13*, 65–71. [CrossRef]
33. Bilgic, G.; Citak Bilgin, N. Relationship Between Fear of Childbirth and Psychological and Spiritual Well-Being in Pregnant Women. *J. Relig. Health* **2021**, *60*, 295–310. [CrossRef] [PubMed]
34. Coty, M.-B.; Wallston, K.A. Roles and well-being among healthy women and women with rheumatoid arthritis. *J. Adv. Nurs.* **2008**, *63*, 189–198. [CrossRef] [PubMed]
35. Jradi, H.; Abouabbas, O. Well-Being and Associated Factors among Women in the Gender-Segregated Country. *Int. J. Environ. Res. Public Health* **2017**, *14*, 1573. [CrossRef]
36. Kyrolainen, A.-J.; Gillett, J.; Karabin, M.; Sonnadara, R.; Kuperman, V. Cognitive and social well-being in older adulthood: The CoSoWELL corpus of written life stories. *Behav. Res. Methods* **2022**, 1–25. [CrossRef]
37. Alcaniz, M.; Riera-Prunera, M.-C.; Sole-Auro, A. "When I Retire, I'll Move Out of the City": Mental Well-being of the Elderly in Rural vs. Urban Settings. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2442. [CrossRef] [PubMed]
38. Ali, S.F.; Semma, B.; Thornhill, C.W.; Castillo, L.G. Eudaimonic Well-Being for Lesbian and Bisexual Women: The Roles of Religion and Social Connectedness. *J. Homosex.* **2022**, *69*, 1066–1080. [CrossRef] [PubMed]
39. Mir, S.; Naz, F. Spousal Psychological Violence, Coping Strategies and Psychological Well-Being in Married Women. *FWU J. Soc. Sci.* **2017**, *11*, 242–253.
40. Pilar Matud, M.; Lopez-Curbelo, M.; Fortes, D. Gender and Psychological Well-Being. *Int. J. Environ. Res. Public Health* **2019**, *16*, 19.
41. Tan, W.H.; Sheffield, J.; Khoo, S.K.; Byrne, G.; Pachana, N.A. Influences on Psychological Well-Being and Ill-Being in Older Women. *Aust. Psychol.* **2018**, *53*, 203–212. [CrossRef]
42. Joshanloo, M.; Sirgy, M.J.; Park, J. Directionality of the relationship between social well-being and subjective well-being: Evidence from a 20-year longitudinal study. *Qual. Life Res.* **2018**, *27*, 2137–2145. [CrossRef]
43. Alawiyah, T.; Held, M.L. Social Capital: Promoting Health and Well-Being Among Indonesian Women. *Affil.-J. Women Soc. Work* **2015**, *30*, 352–362. [CrossRef]
44. Kettlewell, N.; Lam, J. Retirement, social support and mental well-being: A couple-level analysis. *Eur. J. Health Econ.* **2022**, *23*, 511–535. [CrossRef] [PubMed]
45. Khan, A.; Husain, A. Social Support as A Moderator of Positive Psychological Strengths and Subjective Well-Being. *Psychol. Rep.* **2010**, *106*, 534–538. [CrossRef] [PubMed]
46. Yu, E.; Kim, H.-C. Is she really happy? A dual-path model of narcissistic self-presentation outcomes for female facebook users. *Comput. Hum. Behav.* **2020**, *108*, 106328. [CrossRef]
47. Chapman, B.; Guven, C. Revisiting the Relationship Between Marriage and Wellbeing: Does Marriage Quality Matter? *J. Happiness Stud.* **2016**, *17*, 533–551. [CrossRef]

48. Lim, S.; Raymo, J.M. Marriage and Women's Health in Japan. *J. Marriage Fam.* **2016**, *78*, 780–796. [CrossRef]
49. Hu, M.; Sarwar, S.; Li, Z. Spatio-Temporal Differentiation Mode and Threshold Effect of Yangtze River Delta Urban Ecological Well-Being Performance Based on Network DEA. *Sustainability* **2021**, *13*, 4550. [CrossRef]
50. Song, X.; Tian, Z.; Ding, C.; Liu, C.; Wang, W.; Zhao, R.; Xing, Y. Digital Economy, Environmental Regulation, and Ecological Well-Being Performance: A Provincial Panel Data Analysis from China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11801. [CrossRef]
51. Verhofstadt, E.; Van Ootegem, L.; Defloor, B.; Bleys, B. Linking individuals' ecological footprint to their subjective well-being. *Ecol. Econ.* **2016**, *127*, 80–89. [CrossRef]
52. Gu, M.K.; Sok, S.R. Influence of Leisure Activity Participation Between Genders Among Korean Older Adults. *J. Gerontol. Nurs.* **2018**, *44*, 51–58. [CrossRef]
53. Furuya, S.; Raymo, J.M. Living arrangements, intergenerational support, and married women's subjective well-being. *Asian Popul. Stud.* **2022**, *18*, 87–107. [CrossRef] [PubMed]
54. You, S.; Shin, K. Relationships among exercise beliefs, physical exercise, and subjective well-being: Evidence from Korean middle-aged adults. *Health Care Women Int.* **2017**, *38*, 1263–1274. [CrossRef] [PubMed]
55. Lee, D.M.; Nazroo, J.; O'Connor, D.B.; Blake, M.; Pendleton, N. Sexual Health and Well-being Among Older Men and Women in England: Findings from the English Longitudinal Study of Ageing. *Arch. Sex. Behav.* **2016**, *45*, 133–144. [CrossRef] [PubMed]
56. Cai, X.; Li, Z.; Liang, Y. Tempo-spatial changes of ecological vulnerability in the arid area based on ordered weighted average model. *Ecol. Indic.* **2021**, *133*, 108398. [CrossRef]
57. Ren., B.; Ru, S.; Yao., C. *The Blue Book of Western Region of China: Annual Report on Development in Western Region of China*; Social Sciences Academic Press: Beijing, China, 2013; p. 2021.
58. Fang, C.; Xin, F.; Yi, Z. Prevalence of depressive symptoms and correlated factors among pregnant women during their second and third trimesters in northwest rural China: A cross-sectional study. *BMC Pregnancy Childbirth* **2022**, *22*.
59. Xiao, J.; You, C.; Yong, J. Integrated water resources management and water users' associations in the arid region of northwest China: A case study of farmers' perceptions. *J. Environ. Manag.* **2014**, *145*, 162–169.
60. Liang, H.; Tang, Y.; Huo, X. Liushou Women's Happiness and its Influencing Factors in Rural China. *Soc. Indic. Res.* **2014**, *117*, 907–918. [CrossRef]
61. Yingchun, J.; Zhenzhen, Z. China's Low Fertility Rate from the Perspective of Gender and Development. *Soc. Sci. China* **2020**, *41*, 169–184. [CrossRef]
62. Fuxia, Y.; Mian, Y.; Bing, X.; Qiaoling, L. The effects of China's western development strategy implementation on local ecological economic performance. *J. Clean. Prod.* **2018**, *202*, 925–933.
63. Xinhua Silk Road Information Service. Available online: https://en.imsilkroad.com/p/312941.html (accessed on 12 December 2022).
64. Resource and Environment Science and Data Center. Available online: https://www.resdc.cn/ (accessed on 12 December 2022).
65. Yu, M.; Li, Q.; Hayes, M.J.; Svoboda, M.D.; Heim, R.R. Are droughts becoming more frequent or severe in China based on the Standardized Precipitation Evapotranspiration Index: 1951–2010? *Int. J. Climatol.* **2014**, *34*, 545–558. [CrossRef]
66. China Statistical Yearbook. Available online: http://www.stats.gov.cn/tjsj/ndsj/2020/indexch.htm. (accessed on 12 December 2022).
67. Lasso, M.C.; Urrutia, A.M. HDPI: A Framework for Pollution-Sensitive Human Development Indicators. *Environ. Dev. Sustain.* **2001**, *3*, 199–215.
68. Hsu, C.-C.; Zhang, Y.; Ch, P.; Aqdas, R.; Chupradit, S.; Nawaz, A. A step towards sustainable environment in China: The role of eco-innovation renewable energy and environmental taxes. *J. Environ. Manag.* **2021**, *299*, 113609. [CrossRef] [PubMed]
69. Yibin, S.; Suping, Y. The price index system construction of gender equality. *Stat. Decis.* **2005**, *4*, 58–60.
70. Kobus, M. Polarization measurement for ordinal data. *J. Econ. Inequal.* **2015**, *13*, 275–297. [CrossRef]
71. Li, H. In Theil Index Measurement and Analysis of the Household Income Distribution Gap in China. In Proceedings of the 2010 International Symposium on Labor Employment and Income Distribution Studies, Beijing, China, 13–14 November 2010; pp. 199–205.
72. Kakamu, K. Simulation Studies Comparing Dagum and Singh-Maddala Income Distributions. *Comput. Econ.* **2016**, *48*, 593–605. [CrossRef]
73. Atefoe, E.A.; Kugbey, N. Psychological functioning and well-being among Ghanaian women: A brief report. *J. Psychol. Afr.* **2018**, *28*, 73–76. [CrossRef]
74. Chawla, S.; Sharma, R.R. Enhancing Women's Well-Being: The Role of Psychological Capital and Perceived Gender Equity, with Social Support as a Moderator and Commitment as a Mediator. *Front. Psychol.* **2019**, *10*, 1377. [CrossRef]
75. Yu, M.; Wang, C.; Liu, Y.; Olsson, G.; Bai, H. Water and related electrical energy use in urban households-Influence of individual attributes in Beijing, China. *Resour. Conserv. Recycl.* **2018**, *130*, 190–199. [CrossRef]
76. Cao, L.; Li, L.; Wu, Y. How does population structure affect pollutant discharge in China? Evidence from an improved STIRPAT model. *Env. Sci. Pollut. Res. Int.* **2021**, *28*, 2765–2778. [CrossRef]
77. Li, S.; Zhou, C. What are the impacts of demographic structure on CO_2 emissions? A regional analysis in China via heterogeneous panel estimates. *Sci. Total Environ.* **2019**, *650*, 2021–2031. [CrossRef]

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Small Towns' Functions as a Determinant of the Standard of Living in Rural Areas—An Example from Poland

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Abstract: Rural areas, due to their importance for the economy and society, have always been a subject of efforts to understand and model the growth drivers in these areas as well as to improve the standard of living (SoL) of rural populations. One of the most important factors shaping the functioning of rural areas is the presence of small towns and the number of functions they provide for surrounding areas. The significance of this factor is especially high in peripheral regions, such as the Warmińsko-Mazurskie Voivodship in Poland. Therefore, the aim of this paper was to analyze how the number and structure of functions performed by small towns in the Warmińsko-Mazurskie region affected the standard of living of rural residents in the years 2008–2020. The first part of the analysis was concerned with calculating the number and structure of functions performed by small towns in the region, using methods developed in the framework of urban economic base theory. The TOPSIS method was then used to quantify living standards in rural areas. Finally, the results of the two analyses were compared against each other. The results of the studies show that the standard of living in rural areas usually improved with an increase in the number of functions performed by the small towns. Additionally, the structure of these functions influenced the living conditions of the rural population. However, considering the relative rigidness of the urban network within the regional socio-economic system, it leads to the conclusion that existing disparities in the standard of living will be difficult to reduce in the near future.

Keywords: small towns; rural areas; standard of living; regional and local development

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1. Introduction

Economic growth and development do not progress uniformly across geography. Inequalities are particularly pronounced with regard to urban vs. rural development. Such imbalances may emerge in many aspects, including production structure; employment structure; added value generated; the quality and availability of technical, social and economic infrastructure; accessibility of various services, etc. [1]. This ultimately results in disparities between living standards. If too great, they can lead to negative outcomes, such as population outflow from rural areas, brain drain, and decreased competitiveness—which, in turn, widens the gap even further. Therefore, given the strategic importance of rural areas—especially with regard to their supporting role for the rest of the economy and society—there have been extensive efforts to understand and model the growth drivers in these areas and the determinants of the standard of living (SoL) for rural populations. The importance of the issue is further underscored by the fact that rural areas tend to form the majority of a country's land area and are inhabited by a significant segment of the population. Rural areas make up 93% of Poland's total area and are inhabited by almost 40% of the country's population [2].

Economic analyses point to various determinants of growth, development, and the quality of life for citizens. Improvements in these areas are considered an important sign of

positive economic change. However, it should be stressed that formulating a universal set of drivers—whether of local/regional growth or of living standards—is as inadvisable as it is impossible. After all, factors that serve as economic stimuli can change depending on the level of economic development, the dominant economic paradigm (economic growth and development is spurred by different factors in agrarian, industrial, or service economies), and specific geographical, social, or cultural considerations. Nevertheless, analyses of major growth drivers across different scales—from the micro to the macro—have traditionally pointed at the presence of cities/towns and the number of the functions they provide for surrounding rural areas (and how well they perform them) as a major factor.

Urban centers perform a wide variety of functions for their surrounding areas. At their most general, they consist of relaying demand for goods produced in the surrounding area and ensuring an adequate supply of goods and services (including public ones). Thus, cities/towns influence the incomes and living standards of their population and that of the interlinked rural areas. Large cities have the most pronounced effect due to their socio-economic capacity. However, in low-growth, remote regions with underdeveloped urban networks, it is smaller towns that take on the central role.

This paper is an attempt to analyze how the number and structure of functions performed by small cities in the Warmińsko-Mazurskie Voivodeship in Poland affects the standard of living of rural residents. The voivodship belongs to the one of the least developed regions of Poland with a poorly developed network of large and medium cities so it will be a relatively interesting study area, considering the research goal. We drew on the available literature to put forward the hypothesis that an increase in the number of functions performed by the analyzed towns should be accompanied by an improved standard of living in the surrounding rural areas. We further posited that a function structure dominated by market services would also serve to improve the living conditions of the rural population.

According to the rules adopted by the Polish Central Statistical Office, small towns are urban centers with no more than 20,000 inhabitants. This criterion was also adopted by the authors of this work.

To the best of our knowledge, there has been no other research on this particular subject. Although there is a fairly developed literature on determining the standard of living or quality of life in rural areas, see inter alia [1–11], as well as analyzing urban functions and economic bases, see inter alia [12–18], no such studies have considered the existence of a possible functional relationship between these variables. Determining how the number/structure of urban functions affects the standard of living in the surrounding rural areas may therefore be seen as a novel and a contribution adding value to economics and economic geography. It will also extend our understanding of the mechanisms and drivers of economic growth and development on a local and regional scale, thus helping establish better economic policy.

The paper is structured as follows. After the introductory chapter, we discuss the theoretical aspects of measuring and shaping the standard of living in rural areas, as well as the functions of cities/towns with regard to rural areas. In the following section, we present the methodology for our analyses—i.e., research hypotheses, a methodology breakdown, the timeframe of the study, and data sources. The subsequent subchapters are empirical in nature. First, we report our findings on the number and structure of the functions performed by small towns in the Warmińsko-Mazurskie Voivodeship, then we describe how the standard of living in rural areas of the region varies geographically, and finally, present the relationships between them and discuss the results vis à vis other authors' works. A summary and conclusions are given in the final section.

2. Functions of Cities/Towns with Regard to Economic Growth and Living Standards

Cities and towns play a vital role in socio-economic systems. Their presence and spatial distribution determine the location of many types of economic activities, integrates the effects of the other subsystems in the area, and shapes the living standards of the

population [15,19]. It is also thought that a polycentric layout of urban centers promotes economic performance, social equality, and sustainable management of natural/energy resources [20]. As posited by Belkina et al., the socio-economic status, characteristics, and problems of regions are a function of the economic trends and processes in their constituent cities/towns, as well as of the scale and scope of their functions [21]. It therefore follows that any attempt to quantify the drivers of local and regional developments must be accompanied by an analysis of the socio-economic functions of cities/towns—as in which roles they fulfill and how well they do so.

Economics and economic geography offer varying definitions of urban functions. They are usually defined in terms of the activities that form the bulk of a city's or town's economic potential and its relations with the surrounding area—in other words, the activities that generate the most labor demand and that which shape the life and development of the city and its area [22]. However, urban areas are also systems of interconnected elements and the relationships between them. They vary in complexity, depending on the population, and there is a prevalence of other economic and institutional operators. Moreover, a city/town is an open system in that it forms various relationships with its socio-economic environment [12]. Hence, any analysis of the functional structure of urban centers and their impact on their surroundings must follow a systemic approach. Such an analysis must determine what role the selected elements—in this case, cities and towns—play in the system against a functional whole, and how this whole is structured. In other words, as noted by Suliborski, urban functions can be defined as any type of activity carried out in a city/town that produces an evident surplus in employment compared to the employment structure of the region [23].

This method of identifying and quantifying urban functions relates to the notion of the urban economic base, which is popular in geographic and economic sciences [23,24]. This theory holds that all types of economic activity within an urban area can be separated into two groups (sectors). The first consists of activities that generate finished goods and services sold to markets beyond the city limits. This sector (referred to as the exogenous, economic base, or basic sector) thus serves as a source of income for those involved in this type of production. The second sector (endogenous or servicing sector) is composed of activities aimed at fueling the needs of the city's/town's own citizens. Its effects are thus inward-oriented [12,25]. According to the urban economic base theory, as various exogenous-sector activities increase in number and scale, so too does the revenue of city-based enterprises. This boosts investment and consumption, and the corresponding rise in demand has a knock-on effect of increasing production in the endogenous sector. In the long term, this bolsters the economic growth of a city as a whole [26]. By studying changes in the number and structure of functions performed by cities/towns, it is possible to determine their hierarchy in the settlement network structure and the broader socio-economic structures, as well as their changes over time [27,28].

For the purposes of this study, it is particularly important to identify the functions performed by cities/towns for their regional and local surroundings. The simplest scheme for classifying urban functions for this purpose is to divide them into economic and social functions [21]. Social functions provide a supply of goods and services that enable households to meet their essential needs, satisfy their basic well-being, and improve their standard of living. Economic functions, on the other hand, are further subdivided into [ibid.]:

- production functions, i.e., the production of various physical goods;
- the creation and maintenance of an infrastructure network to allow businesses to enjoy the benefits of their metropolitan siting, and to create an environment for manufacturing products in quantities sufficient for the needs of other entities in the city/town and its surrounding area;
- provision of services that support the operations of physical goods producers.

These functions are intrinsic to all urban centers, regardless of their size and the size of their functionally linked areas. However, it should be noted that large cities do tend to perform more functions. In addition, they can also fulfill specialized functions (referred

to in the nomenclature proposed by W. Christaler as 'higher-order functions'), enhancing the scale and scope of their spatial impact on their own environment. With their specific endogenous capacity, large urban centers create a particularly fertile ground for economic growth and development in today's knowledge economy.

Nevertheless, the literature does not provide conclusive evidence as to whether the presence of large urban centers should be considered a driver of regional development. Some studies have shown that selected regions of the USA and China, adjacent to large cities (especially those that could be classified as metropolitan), developed significantly faster than other regions [29,30]. Similar development trends have also been noted in the Polish economic landscape [31]. However, other studies have found otherwise. For example, European Union regions with settlement structures dominated by small and medium towns were the fastest-growing from 2001 to 2008 [29,30]. This begs the question as to what role small urban centers play in shaping the direction and pace of growth, especially in regard to the surrounding rural areas.

Vaishar et al. and Stoica et al. [14,15] have suggested two ways of looking at the function of small towns in socio-economic systems. The first focuses on large cities and highly urbanized (metropolitan) regions. This view reduces small and medium-sized cities into a minor contributor to socio-economic potential, often relegated to a place for economic activities undesirable in large cities due to their nuisance-generating or non-competitive nature [12]. This is partly due to the fact that large cities receive more support from policymakers for public (education, medical, or cultural) infrastructure [32].

However, from the standpoint of rural areas, towns become an important factor influencing economic processes and the living conditions of the population. This is primarily due to the functions that towns provide in settlement systems. Some of these functions are listed in Table 1 [33].

Table 1. Selected functions of small towns.

Function	Description
Supply	Relates to selling products and providing services to surrounding communities. Geographically, this function is usually limited to the nearest rural areas. Agriculture around small and medium-sized cities is particularly reliant on the ability of these units to supply sufficient factors, means, and the tools necessary for this sector [34].
Housing	Ensuring adequate buildings, accommodation, and commercial premises for residents and users of the town. In this regard, small cities represent a continuum of sorts between highly urbanized and rural areas. This makes them a "best of both worlds" option, as they can provide the benefits of living in an urbanized area (agglomeration benefits, better access to public services, etc.) and advantages of living in rural areas, while simultaneously avoiding the "barriers to entry" typical of large cities [32].
Support for the local labor market	Enterprises located in small and medium-sized cities increase demand for labor, not only in the cities themselves, but also in their immediate area. Thus, they provide a source of additional income and a catalyst for greater diversification of production in rural areas. It also stimulates the demand and supply effects generated by small towns.
Cultural	Satisfying the non-physical needs of the population through culture, recreation, and tourism.

This set neglects to include another "obvious" function of small towns—relaying demand for agricultural goods produced in their surroundings. This, importantly, is not just the demand reported by the urban residents themselves. After all, these centers

form one link in the distribution chain of agricultural products (from producer to final user/processor) [35]. The economic links forged in the broader regional and national context between rural areas and small towns, and between towns and large cities, create conditions for diversified economic development and better redistribution of agriculture-generated income [36–39].

In short, small urban centers are a vital component of regional and local socio-economic systems. They shape the living conditions of not only the urban population, but of the surrounding rural areas as well. Towns are a source of labor demand and income for the rural population, as well as health, education, social welfare, administration, and transportation services, among others. The greater the scale and scope of their functions, the greater their capacity as drivers of growth and economic development in rural areas [32]. Small urban centers play a greater role in shaping local and regional development in areas with less developed city networks and lower urbanization. Studies conducted by the ESPON (European Observation Network for Territorial Development and Cohesion) stress that small and medium-sized cities should guarantee access to the full array of higher-order services in areas removed from the influence of large urban centers [40,41].

3. Materials and Methods

The aim of this study is to determine how the number and structure of the functions performed by small towns in the Warmińsko-Mazurskie Voivodeship affects the standard of living in the surrounding rural area. This paper tests the hypothesis that an increase in the number of functions performed by towns leads to a higher standard of living for the rural population. We further posited that a function structure with a high share of market services would also lead to similar improvements.

When examining the functions of urban centers in local and regional functional systems, a key issue that needs to be addressed is how to define such functions and, if possible, measure their scale/scope. As mentioned earlier, urban functions should be understood in the context of wider socio-economic and settlement systems. From this standpoint, a city/town mainly serves to satisfy those needs that cannot be met by entities based around it. As an agglomeration's activity structure becomes more unique and divergent compared with its surroundings, more functions can be ascribed to it.

As such, for the purposes of this study, urban functions have been defined as activities with increased employment (overemployment) compared to the voivodeship's employment structure. Urban economic activities were identified based on data from the public statistical database—i.e., the Polish Classification of Economic Activities (PKD). The database provides a hierarchic classification of all economic activities carried out in Poland, which are arranged in homogenous groups called "sections" (the broadest category). These are further subdivided into divisions, groups, classes, and sub-classes. Each section is designated by a letter from A to U. The system is based on the European statistical classification of economic activities—a statistical reporting scheme maintained for the EU.

The number of functions for Warmińsko-Mazurskie towns was calculated from the overemployment indicator. The measure, commonly used for analyzing urban economic bases, makes it possible to identify areas of production (which, in this study, correspond to PKD sections) in a given city/town with employment greater than the voivodeship average. Overemployment (OE) is calculated using the following formula [42]:

$OE = EiT - (ET \times EiR/ER)$, where:

EiT—employment for the i-th PKD section in the town;

ET—total employment in the town;

EiR—employment for the i-th PKD section in the region;

ER—total employment in the region.

Positive values indicate that the given type of activity is overrepresented in the given town's economy compared to the regional average. These activities therefore feed into the economic base sector and influence the structure of their respective functions. In addition, overemployment in a given section—whether in nominal (as the number of people

employed in the section) or relative terms (as the share of total or working population in the town)—correlates with the importance and scope of the corresponding function in local socioeconomic systems. In effect, the number of PKD sections with above-average employment in a given town can be used to determine the number of functions performed by that town.

The primary urban functions can be singled out by adding up the overemployment values from each PKD section into the corresponding production sector (agriculture, industry, market services, and non-market services). Market service-dominated functional structures are generally considered to be better; this is because service activities generate more added value and are less susceptible to collapse in external demand. In addition, service enterprises form stronger relationships with other entities in local communities, which fosters human capital growth in the long term [43,44]. Therefore, localities where market services are the major sector—whether in nominal or relative terms—are characterized by a higher level and pace of economic growth, which is corroborated by the author's other selected studies on the Polish economy [12,45]. In order to classify small towns in the Warmińsko-Mazurskie Voivodeship according to the primary production sector in their functional structure, we aggregated employment in the different PKD sections and then calculated their share in the total employment in exogenous sectors. The following production sectors were included:

- Agriculture (A)—section A;
- Industry (P)—sections B, C, D, E, F;
- Market services (R)—G, H, I, J, K, L, M, N, R, S, T, U;
- Non-market services (N)—O, P, Q (PKD 2007 names the following sections: A—agriculture, forestry, hunting, and fishing; B—mining and quarrying; C—manufacturing; D—electricity and gas supply; E—water supply and waste management; F—construction; G—trade and repair of motor vehicles; H—transportation and storage; I—accommodation and food service activities; J—information and communication activities; K—financial and insurance activities; L—real estate activities; M—professional, scientific, and technical activities; N—administrative and support service activities; O—public administration and defense, as well as compulsory social security; P—education; Q—human health services and social work activities; R—arts, entertainment, and recreational activities; and S,T,U—other service activities).

Towns were classified by the structure of the economic base and by the direction and degree of change, using the Ossan triangle method [46]. A, P, R, and N type towns are those where one sector dominates over all others in the employment structure. Mixed types (PR, PN, RP, etc.) are those where one sector holds a simple or absolute majority (37.5–75.0%) accompanied by a large (but less than 50%) share of one other. There are also balanced structures, where each sector has a similar share in total employment (within the range of 25.0–50.0%) [ibid.].

These data were then compared against the synthetic SoL measure for the town-adjacent (in the Polish administrative division, the commune (gmina) is the smallest local government unit for a specific territory (NUTS 5); the settlement structure of rural communes is entirely or primarily composed of villages) rural communes.

A synthetic living standard indicator was calculated using TOPSIS [47], a method commonly used in economic research [48–55]. The method weighs decision alternatives by measuring their distance from two reference points—the PIS (positive ideal solution) and the NIS (negative ideal solution). The system identifies the best decision as the one closest to the PIS and furthest from the NIS. The procedure is performed in several steps. First, a decision matrix is built:

$$X = [x_{ij}] \text{ and weight vector } w = [w_1, \ldots, w_n], \text{ where } w_1 + \ldots + w_n = 1. \quad (1)$$

The next step is to build a normalized decision matrix $N = [z_{ij}]_{mxn}$, where z_{ij} is the value of the normalized decision alternative assessment, according to the formula:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} (x_{ij}{}^2)}} \tag{2}$$

where i = 1, . . . , m, j = 1, . . . , n.

The next step is to build a normalized weighted decision matrix:

$$W = [v_{ij}]_{mxn}, \text{ where } v_{ij} = w_j z_{ij}. \tag{3}$$

Then, the positive ideal solution A^+ and negative ideal solution A^- are determined as follows:

$$A^+ = \left[v_1^+, \ldots, v_n^+\right] \text{ where } v_j^+ = \begin{cases} \max v_{ij}, & v_{ij} \in Z \\ \min v_{ij}, & v_{ij} \in S \end{cases} \tag{4}$$

$$A^- = \left[v_1^-, \ldots, v_n^-\right] \text{ where } v_1^- = \begin{cases} \min v_{ij}, & v_{ij} \in Z \\ \max v_{ij}, & v_{ij} \in S \end{cases} \tag{5}$$

The next step is to calculate the distance ($d_i{}^+$) of the i-th decision alternative from A^+ and the distance ($d_i{}^-$) of the i-th decision alternative from A^-,

$$d_i^+ = \sqrt{\left(v_{ij} - v_j^+\right)^2}, \; d_i^- = \sqrt{\left(v_{ij} - v_j^-\right)^2} \tag{6}$$

where i = 1, . . . , m.

This allows the value of the synthetic assessment measure (the global score) to be calculated for the i-th decision alternative, according to the formula:

$$T_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{7}$$

where i = 1, . . . , m. The value of $T_i \in [0,1]$.

Finally, the decision alternatives are ranked in a decreasing order of the synthetic assessment score. The higher the score, the higher the alternative was ranked.

As noted earlier, it is impossible to formulate a fully comprehensive set of living standard metrics. Such measures are typically questionable and arbitrary, making it difficult to compare results. Nevertheless, any set of variables intended to be an authentic description of living standards must be grounded in the literature and meet certain statistical criteria [56], particularly measurability and reliability. In addition, the set should draw on spatially diverse and non-overlapping data. The main challenge in selecting the variables was the settlement unit in question. Much of the targeted data is not published at the level of Polish communes (NUTS 5), which inevitably limits the final set. However, we made our best effort in making the scope be as broad as possible. As such, the variables incorporated into the synthetic measure of the standard of living (SoL) relate to various aspects of life, i.e., the labor market, demographics, and housing. Environmental, cultural, infrastructure, and local government finance indicators were also included. The final number of variables was thus a compromise between expectations and the formal/statistical realities. This synthetic SoL indicator drew on the following components (Table 2):

Table 2. Set of variables included in the synthetic indicator of living standards.

No	Variable Name	Variable Type
1	Commune's own income per capita	Stimulant
2	Total communal expenditures per capita	Stimulant
3	Communal expenditures on municipal services and environment protection per capita	Stimulant
4	Communal expenditures on culture and protection of national heritage per capita	Stimulant
5	Entities entered in the REGON business register per 10,000 population	Stimulant
6	Business environment institutions per 10,000 population	Stimulant
7	Share of registered unemployed persons in working-age population (%)	Destimulant
8	Post-working age population per 100 inhabitants of working age	Destimulant
9	Children in pre-school education institutions per 1000 children aged 3–5 years	Stimulant
10	Newly commissioned dwellings per 1000 population	Stimulant
11	Central heating coverage (%)	Stimulant
12	Wastewater treatment coverage (%)	Stimulant
13	Foundations, associations, and social organizations per 10,000 population	Stimulant

This study draws on data from 2008–2020, which is a period that is limited by the availability of comparable statistics. The data were sourced from the public statistical database published by the Local Data Bank of Statistics Poland (Główny Urząd Statystyczny—Bank Danych Lokalnych). We used Statistica software for visualization.

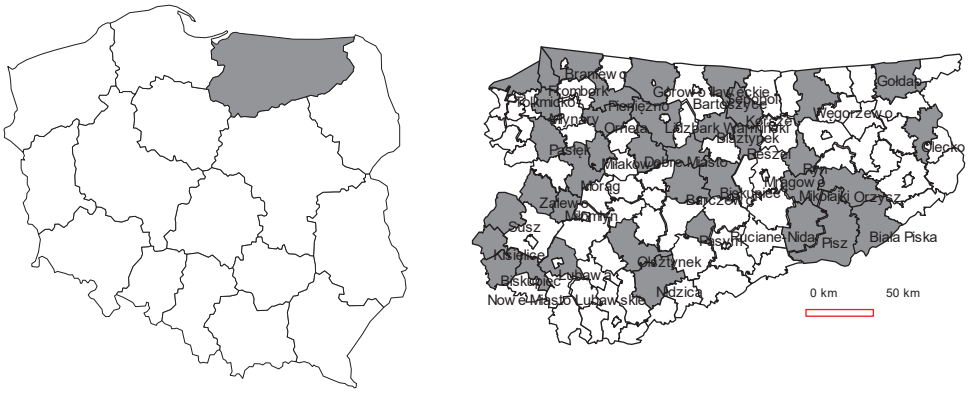
4. Study Area

The Warmińsko-Mazurskie Voivodeship (i.e., province) and its towns—which are the subject of this analysis—are no exception to this rule. The voivodeship still counts among the less developed Polish regions, with a relatively poor and non-competitive production structure. The regional GDP is dominated by low-tech economic activity with little added value and low human capital saturation. The voivodeship's placement near Poland's northern border (in the vicinity of the Kaliningrad Oblast), relatively low transport accessibility, and its social profile are firmly those of a peripheral region [3; 4]. The low economic potential of the region is further limited by the relatively low urbanization. The total number of urban agglomerations is small (49) and mostly dominated by towns (38 during the period considered). As a result, the urban density index (the voivodeship's area per one city/town) is one of the highest in Poland at 493.7 km^2. Only two urban centers in the region (the regional capital of Olsztyn, and Elbląg) can be classified as large cities with 100,000 or more inhabitants. Furthermore, these two cities are relegated to the western and central parts of the voivodeship, along with most medium-sized cities. This, together with

the relatively underdeveloped transportation network, means that residents of the eastern part of the region have no convenient and quick access to higher-order public services. Given these considerations, small towns become much more important as the local loci of growth.

The urban network of the Warmińsko-Mazurskie Voivodeship consisted of 50 towns and cities in 2020. Of these, only two (Olsztyn and Elbląg) can be classified as large cities according to the criteria used by Statistics Poland (a population of over 100,000). Another nine have populations between 20,000 and 100,000, placing them in the category of medium-sized cities. The remaining agglomerations (39) are small towns, with populations not exceeding 20,000. The 2008 set of agglomerations has since expanded to include one new town, i.e., Wielbark. However, no 2008 statistics were available for Wielbark, as such the town was excluded from analysis. This study thus encompassed 38 urban centers that had town privileges as was at the time of the beginning of the considered period. It should also be noted that none of the towns in the Warmińsko-Mazurskie Voivodeship experienced sufficient changes in population between 2008 to 2020 to change their classification (according to size).

At the end of 2008, the small towns covered by this study had a combined population of 279,391, which accounted for 19.6% of the total voivodeship population and 32.7% of the region's urban population. By 2020, the towns' population had declined to 271,794, accounting for 19.2% of the region's total population and 32.5% of the urban population. Town (population) size averaged 7352 residents in 2008 and 7152 in 2020. Młynary was the smallest town of the group across the entire period considered, with a population of 1815 in 2008 (1763 in 2020). The largest town within the sample was Pisz, with a population of 19,451 in 2008 and 19,029 in 2020. Only 8 of the towns experienced any population growth. The greatest increase—both in nominal and relative terms—was noted for Lubawa, whose population increased by 850 (8.9%) over the period considered. Two of the towns—Zalewo and Biała Piska—saw relatively small increases, by 17 and 20, respectively. The largest nominal decline was observed for Nidzica, whose population shrank by 1056—a 7.2% decrease compared to 2008. In relative terms, depopulation was the most pronounced in Górowo Iławeckie—a 11.8% drop (519 people) between 2008 and 2020. The locations of the Warmińsko-Mazurskie Voivodeship and its rural areas that were studied in the paper are highlighted in Figure 1.



(**a**) (**b**)

Figure 1. (**a**) Warmińsko-Mazurskie on the map of Poland and (**b**) rural areas from the study.

These data show that the sampled towns represent a significant portion of the region's total and urban demographics. Despite this, however, there was a noticeable nominal

and relative decline in the population, which may indicate some structural limitations in their development and functions. This may have contributed to the marginalization of Warmińsko-Mazurskie towns as local loci of growth and catalysts for rural development. However, this hypothesis will have to be validated by further research.

4.1. Small Towns and Their Functions in the Warmińsko-Mazurskie Voivodeship from 2008 to 2020

Table 3 shows the size of the economic-base sector (in both nominal and relative terms) and the number of functions for the analyzed Warmia, Mazury, and Powiśle towns in 2008 and 2020.

Table 3. Number of functions and size of the exogenous sectors for Warmińsko-Mazurskie Voivodeship towns (2008 and 2020).

Town	Size of Economic-Base Sector (in Number of Population)			Size of Economic-Base Sector (as % of City Population)			Number of Functions		
	2008	2020	Change	2008	2020	Change	2008	2020	Change
Barczewo	47	107	61	0.64	1.43	0.79	3	1	−2
Biała Piska	181	151	−30	4.49	3.74	−0.75	4	3	−1
Biskupiec	428	797	369	4.15	7.52	3.36	3	5	2
Bisztynek	30	114	83	1.24	4.81	3.57	2	3	1
Braniewo	697	529	−168	3.93	3.10	−0.83	8	10	2
Dobre Miasto	785	804	19	7.49	7.85	0.36	3	2	−1
Frombork	45	29	−16	1.82	1.21	−0.61	3	1	−2
Gołdap	412	601	189	3.11	4.38	1.27	6	8	2
Górowo Iławeckie	105	175	70	2.38	4.41	2.03	3	4	1
Jeziorany	50	48	−2	1.47	1.49	0.02	2	2	0
Kisielice	87	110	24	3.87	5.24	1.36	1	2	1
Korsze	50	0	−50	1.11	0.00	−1.11	3	0	−3
Lidzbark	379	266	−113	4.64	3.40	−1.24	2	4	2
Lidzbark Warmiński	504	418	−85	3.09	2.64	−0.45	6	7	1
Lubawa	2212	2419	207	23.23	23.31	0.08	2	1	−1
Mikołajki	62	60	−1	1.64	1.57	−0.07	3	3	0
Miłakowo	157	140	−17	5.85	5.48	−0.37	3	2	−1
Miłomłyn	62	29	−34	2.68	1.18	−1.50	3	1	−2
Młynary	86	140	55	4.72	7.88	3.16	2	1	−1
Morąg	744	703	−41	5.26	5.08	−0.18	5	4	−1
Nidzica	380	504	124	2.60	3.65	1.04	6	2	−4
Nowe Miasto Lubawskie	617	631	14	5.58	5.78	0.20	5	2	−3
Olecko	582	905	323	3.61	5.49	1.88	5	4	−1
Olsztynek	75	432	357	0.99	5.70	4.71	3	4	1
Orneta	333	124	−209	3.59	1.40	−2.19	3	5	2

Table 3. *Cont.*

Town	Size of Economic-Base Sector (in Number of Population)			Size of Economic-Base Sector (as % of City Population)			Number of Functions		
	2008	2020	Change	2008	2020	Change	2008	2020	Change
Orzysz	124	117	−7	2.15	2.10	−0.05	4	2	−2
Pasłęk	340	427	87	2.81	3.50	0.69	7	5	−2
Pasym	66	13	−53	2.59	0.52	−2.06	3	1	−2
Pieniężno	96	116	20	3.36	4.22	0.86	6	5	−1
Pisz	413	320	−93	2.12	1.66	−0.47	5	7	2
Reszel	275	204	−71	5.55	4.47	−1.08	6	6	0
Ruciane-Nida	161	80	−81	3.41	1.79	−1.62	4	2	−2
Ryn	7	58	51	0.24	2.04	1.80	3	2	−1
Sępopol	36	30	−6	1.78	1.55	−0.23	1	1	0
Susz	266	151	−114	4.75	2.72	−2.03	4	5	1
Tolkmicko	26	51	25	0.95	1.88	0.93	3	1	−2
Węgorzewo	601	469	−133	5.21	4.13	−1.08	7	8	1
Zalewo	425	441	16	20.11	20.36	0.26	2	1	−1

Taking into account the specifics of the data collection, the presentation methodology of the Polish Classification of Activities, and our own methodology of analyzing urban economic bases, the Polish literature on the subject divides urban centers into three classes, according to the range of functions they perform. If a city/town serves less than six functions (i.e., the number of PKD sections that are overrepresented in terms of employment) then its exogenous sector is defined as undeveloped. At six to eight functions, the exogenous sector is considered average in terms of development. Any more than that, and the agglomeration is considered to have a developed exogenous sector [23].

It follows that the majority of Warmińsko-Mazurskie towns had a poorly developed exogenous sector. Towns that fit this description numbered 25 (66%) in 2008, rising to 32 (84%) by 2020. There was only one town with a developed exogenous sector in 2020, and none such towns in 2008. In the context of our hypothesis, the fact that 21 (55%) of the sampled towns had a decreasing set of functions, whereas 13 (34%) had a growing one, is a negative trend. The decreases mainly affected the smallest agglomerations (with populations averaging 6516 in 2008).

The presented data show that the small towns of the Warmińsko-Mazurskie Voivodeship are a fairly varied group in terms of their functional range and exogenous sector size. The best-case scenario is a town that combines both aspects, i.e., performs a large number of functions and has a large exogenous sector. The rationale is that such a center could offer a wide range of goods and services for local communities, while also generating the strongest impetus for growth in the form of jobs, employment income, and other income generated through the production of goods and services.

The towns that are best developed in this regard are Reszel, Pasłęk, Lidzbark Warmiński, Gołdap, Węgorzewo, and Braniewo. All of these performed at least six functions (both in 2008 and 2020), while also having the largest exogenous employment. There are certain notable trends in this group. In Braniewo, Węgorzewo, and Gołdap, i.e., the most remote of the towns (located near the northern border of the voivodeship and Poland, and situated far from the region's largest cities, with poor transport accessibility), the highest rates of overemployment were in sections O, P, and Q—education and administration. These activities belong to the non-market services sector, publicly funded from local and national budgets. In the case of Węgorzewo and Gołdap, slightly above-average labor engagement

was noted in sections related to tourism, which can be attributed to the natural beauty of their surrounding areas and their siting on the popular Great Mazurian Lakes route. In the other towns, functions centered around sections C (manufacturing); D and E (electricity and water supply); and G and H (trade, transport, and storage).

On the other hand, the smaller towns tended to have less functions across the entire period. These towns also had the poorest average rates of employment in the exogenous sector. Exogenous employment for towns with the largest number of functions averaged 546 people in 2008 and 399 people in 2020, whereas towns with an underdeveloped exogenous sector employed just 252 and 270 people, respectively. Moreover, even these values were heavily inflated by two cities—Lubawa and Dobre Miasto, whose exogenous sectors exceeded 2000 and 700 people, respectively, in both years The high rates of exogenous employment in these two agglomerations are generated by the furniture factories located on their territory, the largest in the voivodeship (IKEA, BlackRedWhite, and DFM, among others. For the majority of Warmia, Mazury, and Powiśle, i.e., towns with small functional ranges, overemployment was mostly relegated to PKD sections O, P, and Q—in other words, non-market service functions. This suggests that the economic potential and investment attractiveness of these centers is so low that the various public government institutions and their subordinate units are the largest employers. The only exceptions are small towns with larger industrial plants (often legacy facilities established during the centrally planned economy of the communist era), where exogenous employment is dominated by PKD section C (manufacturing); as well as towns neighboring Olsztyn (the largest city in the region and its administrative capital). Some exogenous employment was also noted in sections G (trade) and F (construction).

Table 4 shows a breakdown of the functions performed by small towns in the Warmińsko-Mazurskie Voivodeship in regard to their dominant production sector. A consistent trend throughout the period that was considered is that most towns were centered around industrial functions—20 (53%) in 2008 and 21 (84%) in 2020. Of these, the majority had an underdeveloped exogenous sector, meaning that they performed relatively few functions. Non-market services were also highly prolific in the functional structure of many Warmińsko-Mazurskie towns. Such urban centers numbered 14 (37%) in 2008, dropping to 8 (21%) by 2020. These also followed a distinctive pattern, as most had small populations and a remote location, highly removed from the largest cities in the region. In 2008, four of the towns relied on market services as the chief component of their functional structures, a number which grew to six by 2020. However, one distinguishing feature was that they had good potential for supporting tourism or were situated relatively close to the largest cities in the region.

Table 4. Small towns of the Warmińsko-Mazurskie Voivodeship according to their dominant functions in 2008 and 2020.

Town	2008	2020
Barczewo	N	R
Biała Piska	N	NR
Biskupiec	R	P
Bisztynek	N	P
Braniewo	N	NR
Dobre Miasto	P	P
Frombork	R	R
Gołdap	P	P
Górowo Iławeckie	N	N
Jeziorany	N	R
Kisielice	N	N
Korsze	P	=
Lidzbark	P	P

Table 4. *Cont.*

Town	2008	2020
Lidzbark Warmiński	P	P
Lubawa	P	P
Mikołajki	P	P
Miłakowo	P	P
Miłomłyn	N	P
Młynary	P	P
Morąg	P	P
Nidzica	P	P
Nowe Miasto Lubawskie	P	P
Olecko	P	P
Olsztynek	R	P
Orneta	P	R
Orzysz	N	R
Pasłęk	P	P
Pasym	N	N
Pieniężno	N	R
Pisz	P	N
Reszel	P	P
Ruciane-Nida	N	N
Ryn	R	P
Sępopol	N	N
Susz	P	P
Tolkmicko	P	N
Węgorzewo	N	N
Zalewo	P	P

The next stage of the analysis focused on determining the standard of living (SoL) for rural communes that neighbored the sampled towns. Values of the synthetic SoL indicator for the different communes are presented in Table 5.

Table 5. Warmińsko-Mazurskie Voivodeship communes ranked by their respective values of the synthetic standard-of-living indicator in 2008–2020.

Town	Rank in 2020	Rank in 2008	Value in 2020	Value in 2008
Mikołajki	1	3	0.592052	0.563631
Olecko	2	2	0.566287	0.60234
Ryn	3	18	0.53262	0.479593
Gołdap	4	1	0.531843	0.633942
Nidzica	5	8	0.516405	0.512916
Olsztynek	6	7	0.514445	0.514519
Barczewo	7	11	0.512071	0.5055
Biskupiec	8	13	0.504075	0.501132
Ruciane-Nida	9	14	0.504035	0.500242
Pisz	10	10	0.502333	0.509771
Frombork	11	12	0.500734	0.503258
Pasym	12	16	0.499361	0.497987
Węgorzewo	13	4	0.477665	0.552737
Tolkmicko	14	17	0.476644	0.486704
Susz	15	26	0.468203	0.404441

Table 5. *Cont.*

Town	Rank in 2020	Rank in 2008	Value in 2020	Value in 2008
Miłakowo	16	22	0.466739	0.419536
Orneta	17	5	0.46651	0.518239
Dobre Miasto	18	6	0.455664	0.517317
Nowe Miasto Lubawskie	19	34	0.453031	0.298194
Morąg	20	9	0.439016	0.510335
Orzysz	21	15	0.437124	0.499588
Młynary	22	29	0.436393	0.402074
Kisielice	23	25	0.436093	0.405121
Miłomłyn	24	30	0.431073	0.37043
Lubawa	25	37	0.427349	0.25072
Pasłęk	26	23	0.422599	0.41605
Korsze	27	28	0.41479	0.4032
Biała Piska	28	27	0.411624	0.404089
Jeziorany	29	20	0.410841	0.426266
Reszel	30	19	0.397477	0.438017
Pieniężno	31	24	0.38993	0.40871
Lidzbark	32	31	0.36623	0.324937
Zalewo	33	21	0.360217	0.420948
Bisztynek	34	33	0.360017	0.308835
Lidzbark Warmiński	35	38	0.354069	0.194952
Braniewo	36	32	0.329823	0.320615
Sępopol	37	35	0.325566	0.279977
Górowo Iławeckie	38	36	0.256242	0.250927

The highest SoL values were reserved for tourist destination communes: Mikołajki, Ryn, and Olecko. However, while the towns of this area can be considered leaders, smaller agglomerations can also provide a high standard of living [57,58]. Tourists are attracted to the area primarily by the lakes and remarkable natural environments, unspoiled by industry. Well-developed recreation and accommodation facilities generate revenue for local government budgets, create income for local residents, and drive municipal infrastructure development [59]. That these towns ranked high on the list should come as no surprise, given the region's relatively low endogenous potential [60]. Their success in this regard is long-standing, as evidenced by their equally high placements in the SoL ranking for 2008.

At the other extreme are communes bordering the Kaliningrad Oblast. The difference is particularly striking with regard to Braniewo, Górowo Iławeckie, and Sępopol—localities characterized by low population density, depopulation, and low concentration of industrial and service activities. Transport-related social exclusion, the "legacy burden" of communist-era farmland control policies ("PGR" state agricultural farms) [61], combined with reduced labor demand and a progressively ageing population , all act as barriers to local growth. This trend is corroborated by past studies [9,62–65].

The "petrification" of the ranking is telling but expected. The best-scoring communes of 2008 remained at the top in 2020. Conversely, the bottom placements also remained

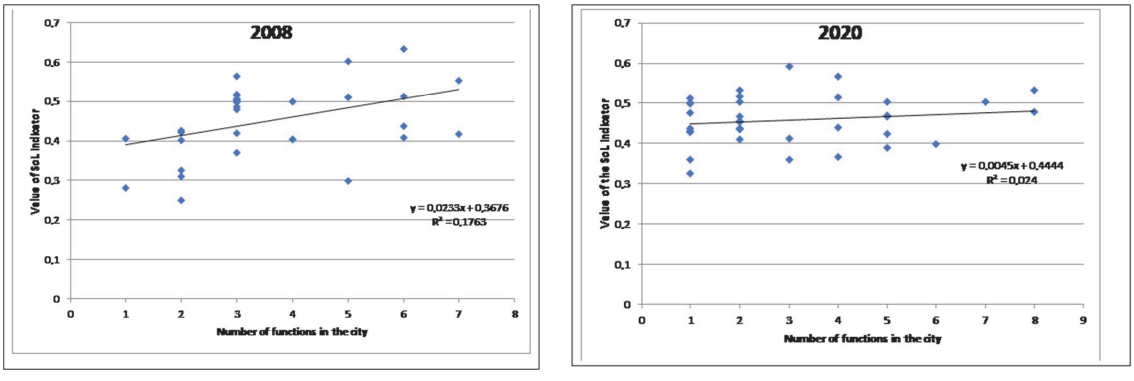
stable over the years. The year 2020 brought some minor reshuffles in the ranking, although the set of communes included was virtually identical.

Having said that, the gap between the highest measured SoL in 2020 (Mikołajki) and the lowest (Górowo Iławeckie) did narrow when compared with 2008. This may hint at a certain convergence of living standards across Warmińsko-Mazurskie's rural areas. Nevertheless, these areas remain some of the poorest in Poland in terms of their SoL [66].

To validate the results, the authors processed the synthetic SoL indicator using the Hellwig method [67], a popular [68] multivariate comparative analysis method used for linear ordering. The results were essentially the same as those obtained via TOPSIS.

4.2. Standard of Living in Rural Areas of the Warmińsko-Mazurskie Voivodeship versus the Number and Structure of Functions Performed by Small Towns

To test our hypothesis, we had to compare the data on the number and structure of functions performed by Warmińsko-Mazurskie towns with the SoL values for the surrounding rural areas. The results of this comparison are shown in Figure 2. The figure also displays regression functions that model the relationship between the studied variables and the corresponding value of the R^2 coefficient of determination. Four towns with extremely high or extremely low values of the variables were removed from the analysis. These outliers were: Braniewo, Górowo Iławeckie, Korsze, and Lidzbark Warmiński.



(**a**) (**b**)

Figure 2. Number of urban functions in Warmińsko-Mazurskie towns versus the TOPSIS-calculated standard of living indicator for their neighboring rural areas2008 (**a**) and 2020 (**b**).

Analysis of the data for the remaining agglomerations hints at several conclusions. Firstly, the number/structure of functions performed by Warmińsko-Mazurskie towns, positively correlated with the SoL in the surrounding rural areas (both in 2008 and 2020), where, notably, the correlation was stronger during the former period.

This means that a broader range of urban functions in Warmińsko-Mazurskie towns led to an improved SoL in their neighboring rural areas. However, the correlation was moderate and varied with time. The correlation coefficient for the 2008 data was 0.42, indicating moderate correlation, and 0.15 for 2020, indicating weak correlation. The positive slopes of the regression lines also indicate a positive relationship between the scope of urban (town) functions and the standard of living in the surrounding rural areas in the voivodeship. However, the low values of the determination coefficient, especially for 2020, preclude a full validation of the hypothesis.

The relationship was notably strongest for towns situated the furthest from the voivodeship's large cities. It mainly includes such agglomerations as Węgorzewo, Olecko, or Pisz, where the relatively high number of functions was coupled with higher levels of development in the associated rural areas. The relationship was less pronounced in towns such as Olsztynek, Nidzica, Dobre Miasto, and Tolkmicko. These towns are situated near

the voivodeship's largest cities, and the limited number and type of their functions may indicate that their role has been relegated to a residential "base" for the cities' working populations. Nonetheless, the income brought in from large cities (regional loci of growth) still serves to fuel economic growth and economic development—not only for these agglomerations, but for the surrounding areas as well. These conclusions are corroborated by findings of other authors who examined spatial patterns of growth and regional development in post-socialist countries, such as Poland [13–15,69]. The authors have noted that remote, underdeveloped regions showed faster economic growth if they were situated close to and were functionally linked with large cities.

Despite their limited range of urban functions, Zalewo, Lubawa, and Młynary were also surrounded by relatively well-off rural areas. In this case, however, this may be attributed to the large employment in the towns' exogenous sectors, forming a strong—albeit monofunctional—economic base. The towns serve as regional manufacturing hubs, mainly focused on wood and furniture processing, which is the primary industrial sector of the Warmińsko-Mazurskie Voivodeship. However, one should be mindful that production monocultures, especially industrial ones, reduce the ability of such areas to build economic resilience [70,71] and increase the risk of a sudden drop in production and spike in unemployment caused by an external demand collapse [72].

The weaker correlation between the 2020 variables may be the product of the EU Cohesion Policy, including Operational Programme Eastern Poland. The program aims to provide targeted support to the least-developed regions of Poland, including the Warmińsko-Mazurskie Voivodeship. While the various projects implemented under the Community Cohesion Policy did not close the development gap between Eastern Poland and the rest of the country to any appreciable extent, the sampled localities did show significant improvements in intraregional terms [73,74]. While the investments in the least-developed communes of the voivodeship may not have produced visible results in 2008, at least some improvement did become apparent by 2020.

There are also interesting conclusions to be drawn from comparing average values of the synthetic SoL indicator for rural communes against the primary function of the associated towns (Table 6).

Table 6. Average values of the synthetic standard-of-living indicator for rural areas versus the primary function of the associated towns (Warmińsko-Mazurskie Voivodeship).

Type of Town	SoL Indicator	
	2008	**2020**
Industrial towns	0.44	0.46
Market service-focused towns	0.50	0.45
Non-market service-focused towns	0.41	0.43

The data in the table indicate that the development of rural areas in the Warmińsko-Mazurskie Voivodeship is correlated with the sectoral structure of urban (town) functions. Invariably, areas around towns reliant on non-market services had the poorest quality of life. On the other hand, areas with service-centered towns were typified by the highest quality of life (with the exception of data for 2020). This validates the hypothesis stated above—that the level and pace of economic growth and development is best fostered by a market service-oriented production structure. Conversely, socio-economic systems dominated by non-market services form a significant barrier to development. Considering the unfavorable demographic trends (emigration, population ageing, etc.), as well as the economic fabric of the region and its agglomerations (17), urban centers of this profile can be expected to grow in number, which would be accompanied by a decreased development potential of the region as a whole.

5. Summary and Conclusions

Economic development processes at different levels of spatial aggregation (from the macroeconomic to the local) are determined by a multitude of factors. These factors may change in significance over time and in response to evolving social, economic, and geographical circumstances. Undoubtedly, however, the presence of cities/towns and the functions they serve for the surrounding environment is a permanent and significant determinant of development. A well-developed network of urban centers that effectively carry out their functions is a driver of cohesion and economic growth/development. As cities/towns take on more functions, especially those that fit well with the current economic paradigm, they become more likely to foster a diversified and developed economy—not only for the city/town itself, but for the surrounding rural areas as well.

Based on these considerations, we put forward the hypothesis that the standard of living (SoL) in rural areas of the Warmińsko-Mazurskie Voivodeship is determined by the range and structure of functions performed by small towns of the region. The first part of our analysis was concerned with calculating the number and structure of functions performed by the small cities of Warmia, Mazury, and Powiśle, using methods informed by urban economic base theory. The TOPSIS method was then used to quantify living standards in rural areas. Finally, the results of the two analyses were compared against each other. This analysis led to several key findings.

Firstly, Warmińsko-Mazurskie towns proved to have a relatively weak exogenous sector throughout the period considered. The size of the economic base (measured by overemployment, i.e., the number of surplus employees, and as a percentage of the labor force) was relatively small over the entire period. As a result, the sector failed to provide a significant impetus for growth in the local economy.

Similarly, the sampled towns did not perform a wide variety of functions—six or less in most cases—which provides further indication of an underdeveloped exogenous sector. Moreover, this means that the population of the sampled towns and the surrounding rural areas has limited access to economic activities typical of urban centers. Combined with the small number of large and medium-sized cities in the region and poor transportation accessibility, this may lead to a reduced standard of living, especially for the rural population.

Industrial activity and non-market services form the largest share of the structural structure in the towns were sampled. These types of activity are typified by relatively poor competitiveness, low innovation, and little added value. This limits the potentially positive impact of the exogenous sector on the economy and living standards for these localities.

Our hypothesis has been partially confirmed by a comparison of exogenous sector size data for Warmińsko-Mazurskie towns with the scores of the synthetic SoL indicator for the surrounding rural areas. In most cases, a broader range of urban functions led to an improved standard of living in the associated rural areas. This correlation was the strongest for areas most removed from the region's largest cities.

Our study also shows a clear relationship between the sector structure of urban functions and the rural standard of living. Functional structures with a dominant share of market services and a high share of industrial activity had the strongest positive effect in this regard.

To the best of our knowledge, there has been no other research on this particular subject. In this sense, our study represents a novel approach to understanding and describing the role of urban centers in shaping the rural standard of living. While the rural SoL is a fairly well-explored line of research with robust methodology, to our best knowledge no such studies have considered the number and type of urban functions as factors affecting SoL. In this regard, our study can also expand the potential scope of spatial analyses of economic growth under economic base theory, and thus serve as a valuable contribution to it. Our work can also serve as a springboard for a theoretical discussion on the determinants of local/regional economic growth and development, and a delineation of a theoretical framework for economic policymaking. Our findings indicate that improving the standard

of living in rural areas requires specific action and investment targeted directly at rural areas and their populations, as well as their neighboring cities and especially towns. A well-developed and diversified exogenous sector in urban centers, focused primarily on market services (as defined in our study) can be an important driver of urban-rural cohesion. Hence, bolstering the exogenous potential of cities—especially small towns functionally linked to rural areas—should be a focus of rural development policy.

In terms of supporting territorial cohesion, it has to be stressed that the network of cities/towns and urban production structures are such a rigid component of regional socio-economic potential that rapid improvements are next to impossible. Any measures aimed at evolving the size and structure of the urban exogenous sector will only bear fruit in the long term. In this respect, it is worth mentioning that to our knowledge none of the authorities of the towns included in the study had included the issue of actions aimed at developing the scale and scope of functions performed by these towns. If such problems are being highlighted in local development strategies, it is usually restricted to developing tourist functions. Additionally, this is far from the point of view of building the potential for sustainable growth in the future and improving the economic resilience of these cities.

We are also cognizant of the various limitations of our study. First of all, quantifying urban functions for Polish cities/towns is complicated by the scarcity of statistical data. In particular, this relates to data for lower-level settlements and detailed data (broken down by sub-section) on economic activity in localities. Secondly, the study design did not address the spatial range of the urban functions nor the specifics of how towns extend their growth-promoting effects onto the surrounding areas. Another limitation, stemming from the pilot nature of the study, is its geographically limited scope. In order to derive more universal conclusions, the sample would have to be expanded to include urban centers of other regions and countries. We will address these considerations in our subsequent research.

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References

1. Buta, A.; Neculita, M.; Cristea, D.; Petrea, S.; Mogodan, A.; Simionov, I. Opportunities of Sustainable Development in the Rural Area at the Level of Galati County, Romania. *Sci. Pap. Ser. Manag. Econ. Eng. Agric. Rural. Dev.* **2020**, *20*, 101–109.
2. Sompolska-Rzechula, A.; Oleńczuk-Paszel, A.; Spiewak-Szyjka, M. Measurement and Evaluation of the Socio-Economic Potential of Rural Areas in Poland. In Proceedings of the 2019 International Conference "Economic Science for Rural Development" No 50, Jelgava, Riga, Latvia, 9–10 May 2019; pp. 186–193. [CrossRef]
3. Bogdański, M. Ewolucja bazy ekonomicznej a wzrost gospodarczy miast województwa warmińsko-mazurskiego. *Stud. Reg. Lokal.* **2019**, *3*, 103–132. [CrossRef]
4. Merlo, P.; Michalak, J.; Bogdański, M. Kapitał ludzki a rynek pracy w województwie warmińsko-mazurskim. In *Efekty Inwestowania w Kształcenie Kadry Menadżerskiej Dla Potrzeb Regionalnego Rynku Pracy*; Merło, P., Michalak, J., Eds.; Wydział Nauk Ekonomicznych, Uniwersytet Warmińsko-Mazurski w Olsztynie: Olsztyn, Poland, 2015; pp. 18–32.
5. Spellerberg, A.; Huschka, D.; Habich, R. Quality of Life in rural areas: Proccesses of divergence and convergence. *Soc. Indic. Res.* **2007**, *83*, 283–307. [CrossRef]
6. Brauer, R.; Dymitrow, M. Quality of Life in Rural Areas: A Topic for the Rural Development Policy? *BGSS* **2014**, *25*, 25–54. [CrossRef]
7. Kalinowski, S. *Poziom Życia Ludności o Niepewnych Dochodach*; PWN: Warsaw, Poland, 2015.

8. Sompolska-Rzechuła, A.; Oleńczuk-Paszel, A. Poziom życia ludności Na Obszarach Wiejskich i Miejskich w Polsce. *Wir* **2017**, *4*, 77–96. [CrossRef]
9. Janusz, M. The standard of living and its spatial differentiation among rural municipalities in Warmia-Masuria province. *Acta Sci. Pol. Adm. Locorum* **2020**, *19*, 5687. [CrossRef]
10. Kalinowski, S. Poverty in Rural Areas: An Outline of the Problem. *Acta Sci. Pol. Oecon.* **2020**, *19*, 69–78. [CrossRef]
11. Rosner, A.; Wesołowska, M. Changes in population in rural areas of Poland as set against their levels of socio-economic development. *Przegląd Geogr.* **2022**, *94*, 175–198. [CrossRef]
12. Bogdański, M. Changes in the functional structure of small towns in the least developed regions of Poland. *Hum. Geogr.* **2021**, *15*, 185–207. [CrossRef]
13. Novotny, L.; Csachova, S.; Kulla, M.; Nesterova-Dicka, J.; Pregi, L. Development Trajectories of Small Towns in East Slovakia. *Eur. Countrys.* **2016**, *8*, 373–394. [CrossRef]
14. Vaishar, A.; Zapletova, J.; Novakova, E. Between urban and rural: Sustainability of small towns in the Czech Republic. *Eur. Countrys.* **2016**, *8*, 351–372. [CrossRef]
15. Stoica, I.-V.; Tulla, A.F.; Zamfir, D.; Petrisor, A.-I. Exploring the Urban Strength of Small Towns in Romania. *Soc. Indic. Res.* **2020**, *152*, 843–875. [CrossRef]
16. Hamdouch, A.; Demaziere, C.; Banovic, K. The Socio-Economic Profiles of Small and Medium-Sized Towns: Insights from European Case Studies. *Tijdschr. Voor Econ. Soc. Geogr.* **2017**, *108*, 456–471. [CrossRef]
17. Olejniczak-Korcelli, E. Functional differentiation of small towns in North-Eastern Poland under a depopulation trend. *Przegląd Geogr.* **2020**, *92*, 191–212. [CrossRef]
18. Śleszyński, P.; Wiedermann, K. Studium szacunku liczby i struktury pracujących oraz bazy ekonomicznej miast w Polsce. *Pr. Kom. Geogr. Przemysłu Pol. Tow. Geogr.* **2020**, *34*, 184–205. [CrossRef]
19. Skrzyp, J. *Polityka Rozwoju Regionalnego. Wybrane Zagadnienia*; Wydawnictwo Akademii Podlaskiej: Siedlce, Poland, 2002.
20. Korcelli, P. Podstawowe węzły układu osadniczego w Polsce na tle europejskiego systemu osadniczego (Aglomeracje-Metropolie). In *Rola Polskiej Przestrzeni w Integrującej się Europie*; Markowski, T., Stasiak, A., Eds.; No. 233; Polish Academy of Science: Warsaw, Poland, 2007; pp. 87–113.
21. Belkina, T.D.; Scherbakova, E.M.; Protokalistova, L.V. Imbalance between Social and Economic Functions of Cities and Regions. *Stud. Russ. Econ. Dev.* **2019**, *30*, 672–681. [CrossRef]
22. Pęski, W. *Zarządzanie Zrównoważonym Rozwojem Miast*; Wydawnictwo Arkady: Warsaw, Poland, 1999.
23. Suliborski, A. *Funkcjonalizm w Polskiej Geografii Miast*; Wydawnictwo Uniwersytetu Łódzkiego: Łódź, Poland, 2010.
24. Walkiewicz, D. *Przemiany Struktury Funkcjonalnej Miast Wojewódzkich w Latach 1975–1995*; Wydawnictwo Uniwersytetu Łódzkiego: Łódź, Poland, 2006.
25. Krikelas, A.C. Why regions grow: A Review of Research on the Economic Base Model. *Econ. Rev.* **1992**, *7*, 16–29.
26. Stawasz, D. *Współczesne Dylematy Zarządzania Rozwojem Miast*; Wydawnictwo Uniwersytetu Łódzkiego: Łódź, Poland, 2016.
27. McFarlane, J.; Blackwell, B.D.; Mounter, S.W.; Grant, B.J. From agriculture to mining: The changing economic base of a rural economy and implications for development. *Econ. Anal. Policy* **2016**, *49*, 56–65. [CrossRef]
28. Wójcik, M.; Tobiasz-Lis, P. Funkcje gospodarcze regionu miejskiego Nowosybirska. Geneza i współczesne trendy rozwojowe. *Przegląd Geogr.* **2016**, *88*, 183–206. [CrossRef]
29. Dijkstra, L.; Garcilazo, E.; McCann, P. The Economic Performance of European Cities and City Regions: Myths and Realities. *Eur. Plan. Stud.* **2013**, *21*, 334–354. [CrossRef]
30. David, Q.; Peeters, D.; Van Hamme, G.; Vandermotten, C. Is bigger better? Economic Performance of European Cities 1960–2009. *Cities* **2013**, *35*, 237–254. [CrossRef]
31. Bogdański, M. Miasta i obszary słabo zurbanizowane a procesy konwergencji gospodarczej w Polsce. *Pr. Nauk. Uniw. Ekon. We Wrocławiu* **2017**, *465*, 40–50. [CrossRef]
32. Yin, X.; Wang, J.; Li, Y.; Feng, Z. Are small towns really inefficient? A data envelopment analysis of sampled towns in Jiangsu province, China. *Land Use Policy* **2021**, *109*, 1–14. [CrossRef]
33. Elsasser, H. Ist eine Kleinstadt mehr als eine kleine Stadt? In *Kleinstädte—Motoren im Ländlichen Raum*; Tagungsband: Vienna, Austria, 1997; pp. 10–18.
34. Evans, H.; Emerys, A. A Virtous Circle Model of Rural-Urban Development: Evidence from a Kenyan Small Towns and Its Hinterland. *J. Dev. Stud.* **1992**, *28*, 640–667. [CrossRef]
35. Ebrahimzadeh, I.; Tayyebi, N.; Shafei, Y. Functional Analysis of Small Towns Economic Role in Rural Development, Case Study: Zahedshahr, Iran. *J. Serv. Sci. Manag.* **2012**, *5*, 269–279. [CrossRef]
36. Rondinelli, D.A. Towns and Small Cities in Development Countries. *Geogr. Rev.* **1983**, *73*, 379–395. [CrossRef]
37. Erickcek, G.A.; McKinney, H. Small Cities Blues: Looking for growth factors in small and medium-sized cities. *Econ. Dev. Q.* **2006**, *20*, 232–258. [CrossRef]
38. Lazzeroni, M.; Bellini, N.; Cortesi, G.; Loffredo, A. The territorial approach to cultural economy: New oppurtinities for the development of small towns. *Eur. Plan. Stud.* **2013**, *21*, 452–472. [CrossRef]
39. Wirth, P.; Elis, V.; Muller, B.; Yamamoto, K. Peripheralisation of small towns in Germany and Japan—Dealing with economic decline and population loss. *J. Rural. Stud.* **2016**, *47*, 62–75. [CrossRef]

40. Szlachta, J. Ośrodki subregionalne w Polsce—Identyfikacja. In *Subregionalne Bieguny Wzrostu w Polsce*; Dziemianowicz, W., Szlachta, J., Szmigiel-Rawska, K., Eds.; Uniwersytet Warszawski, Wydział Geografii i Studiów Regionalnych Uniwersytetu Warszawskiego: Warsaw, Poland, 2011.
41. Heffner, K.; Gibas, P. Centra regionów a spójność regionalna w Polsce. *Pr. Nauk. Uniw. Ekon. Wrocławiu* **2017**, *466*, 98–110.
42. Dacko, M. Badanie stanu bazy ekonomicznej i struktury funkcjonalnej gmin województwa małopolskiego metodami pośrednimi. *Folia Pomeranae Univ. Technoloiae Stetin.* **2008**, *268*, 25–34.
43. Christofakis, M.; Gkouzos, A. Exploration of Localness in the Context of Economic Base: Accessing Evidence from Greek Prefectures. *Urban Reg. Dev. Stud.* **2014**, *26*, 189–202. [CrossRef]
44. Guan, H.; Liu, W.; Zhang, P.; Lo, K.; Li, J.; Li, L. Analyzing Industrial Structure Evolution of Old Industrial Cities Using Evolutionary Resilience Theory: A Case Study in Shenyang of China. *Chin. Geogr. Sci.* **2018**, *28*, 516–528. [CrossRef]
45. Bogdański, M. Ewolucja bazy ekonomicznej a wzrost gospodarczy miast wojewódzkich. *Pr. Nauk. Uniw. Ekon. Wrocławiu* **2018**, *536*, 21–38. [CrossRef]
46. Sokołowiski, D. Baza ekonomiczna większych miast w Polsce w okresie transformacji systemowej. *Przegląd Geogr.* **2008**, *80*, 245–266.
47. Hwang, C.L.; Yoon, K. *Multiple Attribute Decision Making: Methods and Applications*; Lecture Notes in Economics and Mathematical Systems, LNE 186; Springer: Berlin/Heidelberg, Germany, 1981.
48. Łuczak, A.; Kalinowski, S. Assessing the level of the material deprivation of European Union countries. *PLoS ONE* **2020**, *15*, e0238376. [CrossRef]
49. Zhao, D.-Y.; Ma, Y.-Y.; Lin, H.-L. Using the Entropy and TOPSIS Models to Evaluate Sustainable Development of Islands: A Case in China. *Sustainability* **2022**, *14*, 3707. [CrossRef]
50. Bąk, I.; Wawrzyniak, K.; Oesterreich, M. Competitiveness of the Regions of the European Union in a Sustainable Knowledge-Based Economy. *Sustainability* **2022**, *14*, 3788. [CrossRef]
51. Činčikaitė, R.; Meidutė-Kavaliauskienė, I. An Integrated Assessment of the Competitiveness of a Sustainable City within the Context of the COVID-19 Impact. *Sustainability* **2022**, *14*, 7575. [CrossRef]
52. Galik, A.; Bąk, M.; Bałandynowicz-Panfil, K.; Cirella, G.T. Evaluating Labour Market Flexibility Using the TOPSIS Method: Sustainable Industrial Relations. *Sustainability* **2022**, *14*, 526. [CrossRef]
53. Malinowski, M. "Green Energy" and the Standard of Living of the EU Residents. *Energies* **2021**, *14*, 2186. [CrossRef]
54. Kozera, A.; Standar, A.; Satoła, Ł. Managing Rural Areas in the Context of the Growing Debt of Polish Local Government Units. *Agriculture* **2020**, *10*, 376. [CrossRef]
55. Jędrzejczak-Gas, J.; Barska, A.; Wyrwa, J. Economic Development of the European Union in the Relation of Sustainable Development—Taxonomic Analysis. *Energies* **2021**, *14*, 7488. [CrossRef]
56. Zeliaś, A. *Taksonomiczna Analiza Przestrzennego Zróżnicowania Poziomu Życia w Polsce w Ujęciu Dynamicznym*; Wyd. Akademii Ekonomicznej w Krakowie: Kraków, Poland, 2000.
57. Kachniewska, M.A. Tourism development as a determinant of quality of life in rural areas. *Worldw. Hosp. Tour. Themes* **2015**, *7*, 500–515. [CrossRef]
58. Tucki, A.; Pylak, K. Collective or Individual? What Types of Tourism Reduce Economic Inequality in Peripheral Regions? *Sustainability* **2021**, *13*, 4898. [CrossRef]
59. Kozera, A.; Dworakowska-Raj, M.; Standar, A. Role of Local Investments in Creating Rural Development in Poland. *Energies* **2021**, *14*, 1748. [CrossRef]
60. Świdyńska, N.; Witkowska-Dąbrowska, M. Indicators of the Tourist Attractiveness of Urban–Rural Communes and Sustainability of Peripheral Areas. *Sustainability* **2021**, *13*, 6968. [CrossRef]
61. Biegańska, J.; Dymitrow, M.; Grzelak-Kostulska, E. From Policy to Misery? The State Agricultural Farms vs. 'The Rural'. *Quaest. Geogr.* **2019**, *38*, 77–90. [CrossRef]
62. Senetra, A.; Szarek-Iwaniuk, P. The implementation of the Wroclaw taxonomic method for the identification and evaluation of problem areas in the Warmia and Mazury Region in Poland—A case study. *Soc. Econ. Plan. Sci.* **2019**, *67*, 43–57. [CrossRef]
63. Janusz, M. Polarization of Living Standards among Administrative Units Engaged in Cross-Border Cooperation—The Example of Polish Municipalities of Euroregion Baltic. *Sustainability* **2022**, *14*, 680. [CrossRef]
64. Malinowski, M. Institutional Infrastructure and Sustainable Development: Analysis of Eastern Poland Districts. *Stud. Ekon.* **2019**, *384*, 51–69. Available online: https://www.ue.katowice.pl/fileadmin/user_upload/wydawnictwo/SE_Artyku%C5%82y_381_400/SE_384/04.pdf (accessed on 21 August 2022).
65. Malinowski, M. Financial Situation of Local Government Units as a Determinant of the Standards of Living for the Polish Population. *Energies* **2022**, *15*, 5448. [CrossRef]
66. Stanny, M.; Komorowski, Ł.; Rosner, A. The Socio-Economic Heterogeneity of Rural Areas: Towards a Rural Typology of Poland. *Energies* **2021**, *14*, 5030. [CrossRef]
67. Hellwig, Z. Zastosowanie metody taksonomicznej do typologicznego podziału krajów ze względu na poziom ich rozwoju oraz zasoby i strukturę wykwalifikowanych kadr. *Przegląd Stat.* **1968**, *4*, 302–327.
68. Bielak, J.; Kowerski, M. Dynamics of economic development measure. Fiftieth anniversary of publication of the article by prof. Zdzisław Hellwig. *Barom. Reg. Anal. Progn.* **2018**, *16*, 153–165. [CrossRef]

69. Lupascu, M. The Role of Small Towns of the Republic of Moldova in the Context of Regional Development. *J. Contemp. Econ.* **2020**, *5*, 127–132.
70. Drobniak, A. Resilience and Hybridization of Development of Small and Medium Towns in Poland. *Olszt. Econ. J.* **2019**, *14*, 47–62. [CrossRef]
71. Tóth, B.I. Regional economic resilience: Concepts, empirics and a critical review. *Misc. Geographica. Reg. Stud. Dev.* **2015**, *19*, 70–75. [CrossRef]
72. Masik, G.; Sagan, I. Strategie i instrumenty wspierające odporność gospodarczą. Przykład wybranych regionów europejskich. *Stud. Reg. I Lokal.* **2016**, *4*, 5–29. [CrossRef]
73. Bartosiewicz, S.; Stańczyk, E. Ocena efektów realizacji unijnej polityki spójności w Polsce w latach 2004–2017. Kontynuacja weryfikacji wybranych publicystycznych tez nt. dysproporcji regionalnych w poziomie rozwoju społeczno-gospodarczego. In *Mikroekonometria. Teoria i Praktyka*; Bartóg, B., Foryś, W., Eds.; Wydawnictwo Difin: Warsaw, Poland, 2020; pp. 7–22.
74. Szabela-Pasierbińska, E. Ocena Programu Operacyjnego Rozwój Polski Wschodniej 2007–2013. *Społeczeństwo Ekon.* **2018**, *10*, 39–51. [CrossRef]

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Spatial–Temporal Characteristics and Driving Factors of the Coupling Coordination between Population Health and Economic Development in China

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Abstract: Promoting the coordinated development of population health and the economy is an important part of building a "Healthy China" and promoting high-quality economic development. Based on the systematic construction of the population health and economic development evaluation index system, this paper uses the coupled coordination model, geodetector, and geographically weighted regression (GWR) to comprehensively measure the population health level and economic development level at the provincial scale in China in 2000 and 2015, and reveals the spatial and temporal evolution characteristics of the coupled coordination relationship between the population health level and economic development level at the provincial scale in China from 2000 to 2015 and its driving factors. The results show the following: (1) China's population health and economic development are in a high-level coupling stage, and the coupling level increases slightly with time; spatially, two types of running-in coupling and high-level coupling coexist; the coupling degree in the eastern and central regions tends to increase, while the coupling degree in the western region tends to weaken. (2) China's population health and economic development are in a good coupling coordination stage as a whole, and the coupling coordination degree has an increasing trend; spatially, the coupling coordination degree shows high spatial differentiation characteristics in the east and low in the west; the good and high-quality coupling coordination type area tends to expand to the west, while the moderate coupling coordination type area tends to shrink to the west; there is also positive spatial agglomeration of coupling coordination degree, and the spatial agglomeration is gradually enhanced. (3) The coupling coordination of China's population health and economic development is driven by multiple factors such as natural conditions, health resources, culture quality, and urbanization level; the interaction between factors is stronger than that of a single factor, and the driving effect of each factor also shows significant spatial heterogeneity. This study is intended to provide a scientific basis for promoting harmonious population health and economic development.

Keywords: population health; economic development; coupling coordination; driving factors; China

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1. Introduction

Population health is a human capital input required for economic development, which in turn promotes population health enhancement. Since the founding of New China, especially since the reform and opening up, the health status of the population has been continuously improving along with rapid economic development. As of 2019, life expectancy in China has increased to 77.3 years, while infant mortality rate (IMR) and maternal mortality ratios (MMR) have decreased to 5.6 per 100,000 and 17.8 per 100,000, respectively [1], which are generally better than the levels of the world's middle- and high-income countries. While economic development creates material conditions for the improvement of population health, a series of problems that arise in the process of economic development, such as climate change, environmental pollution, and lifestyle changes, also bring new challenges

to the further improvement of population health. For a country with a large population such as China, failure to continuously improve the health of the population during the process of economic development may turn the advantage of human resources into a demographic burden, hiding a significant issue for future high-quality economic development. Population health and economic development are interlinked and interact with each other to promote economic and social progress. The "Healthy China 2030" Planning Outline clearly points out that the coordination between population health development and economic development should be enhanced, and promoting the coordinated development of population health and the economy is of great practical significance for building a "Healthy China", and thus promoting high-quality economic development.

In terms of the impact of economic development on population health, economic development provides the necessary food, nutritional healthcare, and other material conditions for population health promotion. Studies have concluded that economic development has a positive effect on population health improvement [2–6], and when economic development reaches a certain level, the rate of population health improvement tends to diminish, showing a slightly decreasing effect [7,8]. The effect of economic development on population health may not be immediately apparent, and some other studies have found that its cumulative time-lagged effects on population health are stronger than its current effects [9]. In addition, while income levels are increasing with economic development, income inequality has become increasingly prominent and an important constraint to further improvements in population health [10,11]. In terms of the impact of population health on economic development, human capital theory suggests that health, as an important human capital input, is one of the sources of economic growth [12–14]. An increase in the health of the population means an increase in effective labor time and productivity, which in turn affects economic development. Related studies have shown that healthy human capital can directly contribute to economic growth as an input factor in the production of final goods [15–17], but too much healthy human capital may also crowd out physical capital accumulation, which in turn is detrimental to economic growth [18–20]. As research progresses, it is also believed that healthy human capital indirectly contributes to economic growth through mediating factors such as labor supply, labor productivity, and savings rate [21,22]. Due to the improvement of population health, the health consumption demand for health care will also gradually increase, driving the development of the health service industry, so the improvement of population health also helps to promote the optimization and upgrading of economic structure [23]. All of the above studies are one-way analyses of the relationship between population health and economic development, while some studies also confirmed the bidirectional nature of the relationship between population health and economic development in terms of the interaction between the two [24–26]. Grasping the coupled and coordinated relationship between population health and economic development is conducive to a more accurate understanding of the relationship between population health and economic development, but to date, relevant studies only include Li Changda et al., who explored the coupled and coordinated relationship between the construction of "Healthy China" and economic and social development at a provincial scale in 2015 [27], and lacked the examination of the dynamic changes and driving factors of the coupled and coordinated relationship; thus, the research needs to be deepened.

Based on the above evaluation, based on the system coupling theory, this paper uses the coupling coordination degree model, entropy method, geodetector, and GWR to dissect the spatial and temporal characteristics and driving factors of the coupling coordination between population health and economic development at the provincial scale in China from 2000–2015 on the basis of constructing an evaluation index system of population health and economic development, and makes the following research hypotheses: (1) The coupling and coordination between the level of population health and the level of economic development at the provincial scale in China will tend to increase from 2000 to 2015 and show significant spatial differences. (2) The coupled coordination of population health

and economic development in China will be driven by multiple factors such as natural conditions, health resources, culture quality, and urbanization level.

The applied innovations and contributions of this paper are as follows: (1) It further enriches the international research on the interaction between population health and economic development and provides a Chinese case study, which is helpful in providing a reference for better handling the relationship between population health and economic development in the development process at the same stage of development, especially in developing countries. (2) The spatio-temporal evolution characteristics of the coupled coordination relationship between population health level and economic development level at the provincial scale in China from 2000 to 2015 were analyzed, and the interaction of its influencing factors was revealed using a geodetector, and the spatial differences in the effects of its influencing factors were revealed using GWR, which provided a more valuable scientific basis for accurate and locally appropriate coordination of population health and economic development.

2. Data and Methods

2.1. Selection of Indicators

The health level of the population was evaluated by three indicators: Life expectancy, IMR, and MMR, which are the core evaluation indicators of the health level in the national "Healthy China 2030" plan and are also the most important and commonly used indicators in academic research to evaluate the health level of the population [28–31]. Life expectancy reflects the health status of the population in terms of longevity, and it has been widely recognized as the indicator that best reflects the health status of the population [32–34]. IMR and MMR, on the other hand, reflect the health status of the population from the perspective of death, and because of their vulnerability to the external environment, infant and maternal mortality rates can more sensitively reflect the health status of the population in a region influenced by economic development, health care, culture quality [35,36], and have unique advantages in evaluating the health status of the population. Economic development not only refers to the growth of economic scale but also includes qualitative changes, i.e., optimization of economic structure and improvement of economic efficiency. The economic development level draws on the existing authoritative research results [37,38], follows the principles of scientificity, representativeness, and accessibility, and selects 11 indicators from the three dimensions of the economic scale, economic structure, and economic efficiency for comprehensive evaluation. The results of the selection of evaluation indicators for the level of population health and the level of economic development are shown in Table 1.

2.2. Data Sources

The data on population health level evaluation indicators were obtained from the China Statistical Yearbook [39] and the provincial statistical yearbooks. The data on the amount of investment in fixed assets of the whole society in the evaluation index of economic development level were from the China Statistical Abstract [40]. The data on the average wage of employees on duty were from the China Labor Statistical Yearbook [41], and the data on the remaining indexes were from the China Statistical Yearbook [39]; the data are on an annual basis. The study period of this paper is determined as 2000–2015, and limited to the availability of data, the two nodal years of 2000 and 2015 are mainly examined. The spatial scope of this paper was 31 provinces, autonomous regions, and municipalities directly under the central government in mainland China. Hong Kong, Macao, and Taiwan were not included in the study for the time being due to the lack of data, the spatial unit of study is the provincial administrative district. The map data used for the analysis were produced based on the standard map with the review number GS (2020) 4632 from the standard map service website of the Ministry of Natural Resources, and the base map was not modified.

Table 1. Evaluation index system of China's population health and economic development.

Target Layer	System Layer	Indicator Layer	Unit	Indicator Direction	Weights
Population Health Level	Lifespan Status	Life expectancy	Age	+	0.4705
	Death Status	Infant mortality rate (IMR)	‰	−	0.3584
		Maternal mortality ratios (MMR)	1/100,000	−	0.1711
Economic Development Level	Economic Scale	GDP	Hundred million (CNY)	+	0.0904
		Total social fixed asset investment	Hundred million (CNY)	+	0.0782
		Total retail sales of social consumer goods	Hundred million (CNY)	+	0.0911
		Local fiscal general budget revenue	Hundred million (CNY)	+	0.0922
		Urban and rural residents savings deposit balance	Hundred million (CNY)	+	0.0833
	Economic Structure	Share of secondary industry output in GDP	%	+	0.0221
		The proportion of tertiary industry output in GDP	%	+	0.0925
	Economic Benefits	GDP per capita	CNY	+	0.1069
		Per capita disposable income of urban residents	CNY	+	0.1209
		Net income per capita of rural residents	CNY	+	0.0973
		Average wage of employees in employment	CNY	+	0.1250

Note: "+" indicates the positive indicators, "−" indicates the negative indicators.

2.3. Research Methodology

2.3.1. Entropy Value Method

The entropy value method was used to calculate and determine the weights of each evaluation index of population health level and economic development level, and then synthesized the population health level, and economic development level by weighted summation and the calculation steps were as follows:

Data standardization processing: When considering the differences in the order of magnitude and positive and negative directions of each indicator, the raw data were first processed using the polar difference standardization method.

Positive indicators:

$$X_{ik} = \frac{x_{ik} - x_{k\min}}{x_{k\max} - x_{k\min}} \tag{1}$$

Negative indicators:

$$X_{ik} = \frac{x_{k\max} - x_{ik}}{x_{k\max} - x_{k\min}} \tag{2}$$

The weight of the value of indicator k in the i-th provincial unit:

$$Y_{ik} = \frac{X_{ik}}{\sum_{i=1}^{m} X_{ik}} \tag{3}$$

Calculation of the entropy value of the indicator:

$$E_k = -\frac{\sum_{i=1}^{m} (Y_{ik} \ln Y_{ik})}{\ln m} \tag{4}$$

Calculation of indicator weights:

$$W_k = \frac{1 - E_k}{\sum_{k=1}^{n} (1 - E_k)} \tag{5}$$

Weighted summation calculation of population health level and economic development level:

$$L_i = \sum_{k=1}^{n} X_{ik} W_k \tag{6}$$

where: x_{ik} is the value of the k indicator for the i provincial unit, $x_{k\min}$, $x_{k\max}$ are the minimum and maximum values of all provincial cells of the k-index, respectively. X_{ik} is the normalized value of the indicator k of the provincial unit i, m is the number of provincial cells, n is the number of indicators, E_k is the entropy value of the k-index, W_k is the weight of indicator k, L_i is the value of population health level and economic development level for provincial unit i. The results of the weights of each index calculated by the entropy value method are shown in Table 1.

2.3.2. Coupled Coordination Model

1. Coupling degree model

The coupling degree indicates the degree of interaction and interconnection between two or more systems. In this paper, we introduce a coupling degree model to evaluate the degree of interaction between population health and economic development, which was calculated as follows [42]:

$$C = 2\sqrt{\frac{H \times E}{(H+E)^2}} \tag{7}$$

where C is the coupling degree of population health and economic development, and the value range is [0, 1], H is the level of population health, and E is the level of economic development. The higher the value of C, the stronger the degree of interaction between population health and economic development. Drawing on relevant research results [43], the coupling degree of population health and economic development is classified into four types, namely low-level coupling ($0 < C \leq 0.3$), antagonistic coupling ($0.3 < C \leq 0.5$), running-in coupling ($0.5 < C \leq 0.8$) and high-level coupling ($0.8 < C \leq 1$).

2. Coupling coordination degree model

The coupling degree model can analyze the degree of interaction between population health and economic development, but it cannot reflect whether the two are mutually reinforcing at a high level of interaction or closely linked at a low level of interaction [44], i.e., it cannot reflect the level of coordinated development between the two. Therefore, the coupled coordination degree model was further introduced to evaluate the level of coordinated development between population health and economic development, which was calculated as follows [42]:

$$D = \sqrt{C \times T},\ T = \alpha H + \beta E \tag{8}$$

where D is the coupling coordination degree of population health and economic development, and the range of values is [0, 1], C is the coupling degree, and T is the comprehensive coordination index of population health and economic development. α and β are coefficients to be determined and $\alpha + \beta = 1$. This study was conducted to reveal the coupled and coordinated relationship between population health and economic development, treating both population health and economic development as equal without differentiating their importance, so $\alpha = \beta = 0.5$. Furthermore, drawing on relevant research results [43], the coordination degree of population health and economic development was classified into four types, namely low coordination ($0 < C \leq 0.3$), moderate coordination ($0.3 < C \leq 0.5$), good coordination ($0.5 < C \leq 0.8$), and high-quality coordination ($0.8 < C \leq 1$).

2.3.3. Spatial Autocorrelation

Spatial autocorrelation includes global spatial autocorrelation and local spatial autocorrelation. The global spatial autocorrelation was used to measure the degree of global

spatial correlation of the coupling coordination between population health and economic development, measured by Global Moran's I. Global Moran's I takes values in the range of [−1, 1], Global Moran's I > 0. The greater the value, the stronger the spatial agglomeration, and the smaller the value, the stronger the spatial dispersion. Local spatial autocorrelation was used to measure the degree of local spatial correlation between population health and economic development coupling and coordination, measured by Local Moran's I. Local Moran's I > 0 indicates that spatial units with similar attribute values tend to be clustered, and Local Moran's I < 0 indicates that spatial units with similar attribute values tend to be discrete. The formulas of global spatial autocorrelation and local spatial autocorrelation were in accordance with the study of Moran [45].

2.3.4. Geodetector

Geodetector can be used to detect the spatial heterogeneity of geographical things and reveal their drivers [46]. In this paper, we used factor detection and interaction detection in geodetector to analyze the driving factors of the coupled coordination of population health and economic development. Factor detection measures the driving force of each factor by a *q*-value, and interaction detection measures the magnitude of the interaction by calculating the *q*-value of multiple factors acting together and comparing it with the q-value of a single factor acting. The *q*-value is calculated as follows [47]:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{9}$$

where h = 1, 2, ..., L is the number of categorical zones of the driver, and the number of categorical zones uses a five-class discrete scheme of natural breakpoints at a maximum value of q. N and N_h are the number of provincial cells for the country and sub-district h, respectively. σ^2 and σ_h^2 are the variances of the national and sub-region h, respectively. The value of q ranges from [0, 1], and the larger the value, the stronger the driving force of the factor.

2.3.5. Geographically Weighted Regression (GWR)

Unlike traditional regression models that assume data are not spatially correlated and are homogeneously distributed, GWR incorporates the spatial attributes of the data in the model to reveal spatial differences in the relationships of variables and is calculated as follows [48]:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \tag{10}$$

where y_i is the dependent variable (coupling coordination) of the provincial cell i, (u_i, v_i) is the spatial coordinate of provincial cell i, $\beta_0(u_i, v_i)$ is the intercept term of provincial cell i, x_{ik} is the kth independent variable (driver) of the i provincial cell, $\beta_k(u_i, v_i)$ is the regression coefficient of the k independent variable of the i provincial cell and ε_i is the random error term. In the paper, the model analysis was executed with the help of ArcGis 10.3 software (ESRI, Redlands, CA, USA), setting the kernel type as Adaptive Gaussian and the bandwidth method as AICc.

3. Results and Analysis

3.1. Spatial and Temporal Evolution of the Coupling Degree between Population Health and Economic Development

Overall, the mean value of coupling between population health and economic development in Chinese provinces rose slightly from 0.8665 in 2000 to 0.8722 in 2015, at a high level of coupling. In other words, overall, there was a strong interaction between population health and economic development in China from 2000–2015, with the strength of the effect increasing slightly over time.

The map visual representation of the coupling degree of population health and economic development was used to form a map of the spatial and temporal evolution of the coupling degree of population health and economic development from 2000 to 2015 (Figure 1). From Figure 1, it can be found that from 2000 to 2015, there were spatial heterogeneity characteristics in the coupling degree of population health and economic development, and two types of coupling, running-in coupling and high-level coupling, coexist, but the high-level coupling provinces predominate. In 2000, the total number of running-in coupling provinces was eight, accounting for 25.81%, except for the eastern region (the eastern region includes Liaoning, Beijing, Tianjin, Hebei, Shanghai, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan; the central region includes for Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan, Jilin and Heilongjiang; the western region includes Inner Mongolia, Shaanxi, Gansu, Ningxia, Chongqing, Sichuan Guizhou, Yunnan, Guangxi, Xinjiang, Qinghai, and Tibet). In addition to Hainan, the others were mainly distributed in the central and western regions, specifically showing the spatial characteristics of clustering and distribution in two major areas, including the Gansu–Ningxia–Neimenggu–Shanxi–Jilin contiguous distribution area and the Guizhou–Guangxi contiguous distribution area. A total of 23 high-level coupled provinces, accounting for 74.19%, were widely distributed in the eastern, central, and western regions, specifically showing the spatial characteristics of contiguous distribution in other provinces except for Heilongjiang. In 2015, the number of running-in coupling provinces increased by one and the number of high-level coupling provinces decreased by one, and the spatial distribution of abrasive coupling provinces showed an obvious trend of westward shift. Running-in coupling provinces, except Hainan in the east, were located in the western region, which still exhibits the spatial characteristics of clustered distribution in two major areas, including the Qinghai–Gansu–Ningxia contiguous distribution area and the Yunnan–Guizhou–Guangxi contiguous distribution area. The high-level coupled provinces were still widely distributed in the east, central and western regions. From 2000 to 2015, the westward shift in the spatial distribution of Chinese population health and economic development running in coupling provinces reflected that the interaction between population health and economic development tended to increase in the east and central regions, while the interaction between population health and economic development tended to weaken in the west. Further calculation of the average of the coupling degree of each province in the three major regions reveals that the coupling degrees of the eastern, central, and western regions were 0.9316, 0.8303, and 0.8457, respectively, in 2000, while the coupling degrees of the eastern, central and western provinces shifted to 0.9353, 0.8461 and 0.8171, respectively, in 2015, which well confirms this changing trend.

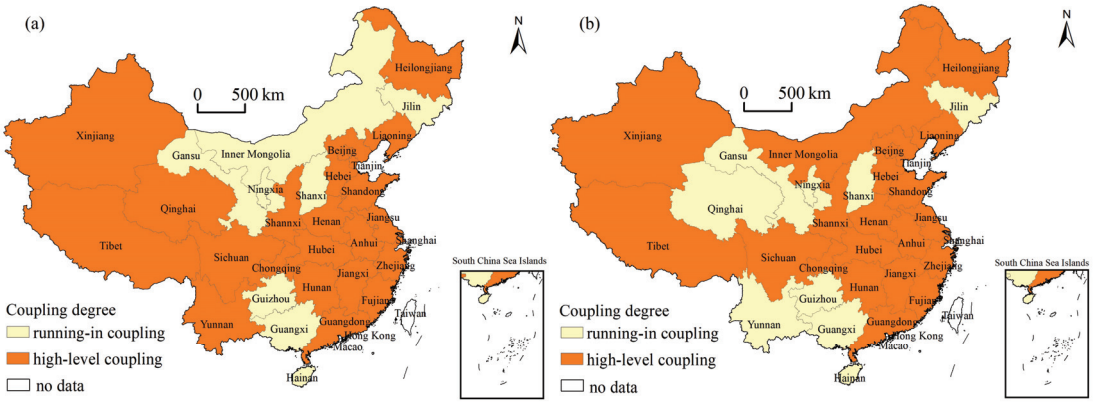


Figure 1. Spatial–temporal evolution of the coupling degree between population health and economic development in China: (**a**) 2000; (**b**) 2015.

3.2. Spatial and Temporal Evolution of the Coordination between Population Health and Economic Development

Overall, the mean value of the coupling coordination between population health and economic development in all provinces of China increased from 0.5999 in 2000 to 0.6624 in 2015, an increase of 10.42% in 15 years, reflecting that China's population health and economic development were in a good coordination stage at this stage, i.e., population health and economic development promoted each other with a higher level of interaction degree, and with this mutual promotion effect, the tendency was to increase.

The coupled coordination degree of population health and economic development in 2000 and 2015 were expressed visually in maps to form the spatial and temporal evolution of the coupled coordination degree (Figure 2a,b). As can be seen from Figure 2a,b, the coupling coordination degree of population health and economic development showed the spatial divergence characteristics of high in the east and low in the west, and there were three coupling coordination types: medium, good, and high quality in space. The area of good and high-quality coupling coordination types tended to expand to the west, while the area of medium coupling coordination types tended to contract to the west. Specifically, the type of quality coupling coordination in 2000 was distributed only in the three eastern provinces of Beijing, Shanghai, and Guangdong, accounting for 9.68%. Good coupling coordination type was widely distributed in the east, central and western regions, including 20 provinces, accounting for 64.52%. The moderate coupling coordination type was all distributed in the western region, covering eight provinces, accounting for 25.80%. Quality coupling coordination type provinces increased to seven in 2015, accounting for 22.58%, all distributed along the eastern seaboard. Good coupling coordination type provinces increased to 21, accounting for 67.74%, still widely distributed in the eastern, central, and western regions, but the distribution range expanded significantly to the west. Moderate coupling coordination type of provinces decreased to three, accounting for 9.68%, with a distribution of further westward contraction, including only the western region of Xinjiang, Qinghai, and Tibet.

The introduction of spatial autocorrelation analysis can further identify the spatial correlation status of the coupling coordination between population health and economic development. The global spatial autocorrelation analysis showed that the Global Moran's I in 2000 and 2015 were 0.2780 ($p < 0.01$) and 0.3089 ($p < 0.01$), respectively, indicating that overall, there was a positive spatial correlation between the coupling coordination of population health and economic development, i.e., there was a spatial clustering between provinces with high values of coupling coordination or between provinces with low values of coupling coordination The spatial distribution tended to be clustered between provinces with high values of coupling coordination or provinces with low values, and this spatial clustering was increasing. As shown in Figure 2c,d, the local spatial autocorrelation visualizes the local spatial correlation status of the coupled coordination degree of population health and economic development in 2000 and 2015. As can be seen from the figure, the high–high concentration areas of the coupling coordination between population health and economic development from 2000 to 2015 were stably distributed in the four eastern provinces of Shandong, Jiangsu, Shanghai, and Zhejiang, while the low–low concentration areas showed an expansion trend. The low–low agglomeration area in 2000 was only distributed in two provinces of Qinghai and Tibet, and in 2015 it was further increased to the two provinces of Xinjiang and Gansu. The high–high clusters remained stable, while the gradual expansion of low–low clusters indicated that the overall spatial clustering of population health and economic development coupling coordination tended to increase, mainly driven by the spatial clustering among provinces with lower coupling coordination.

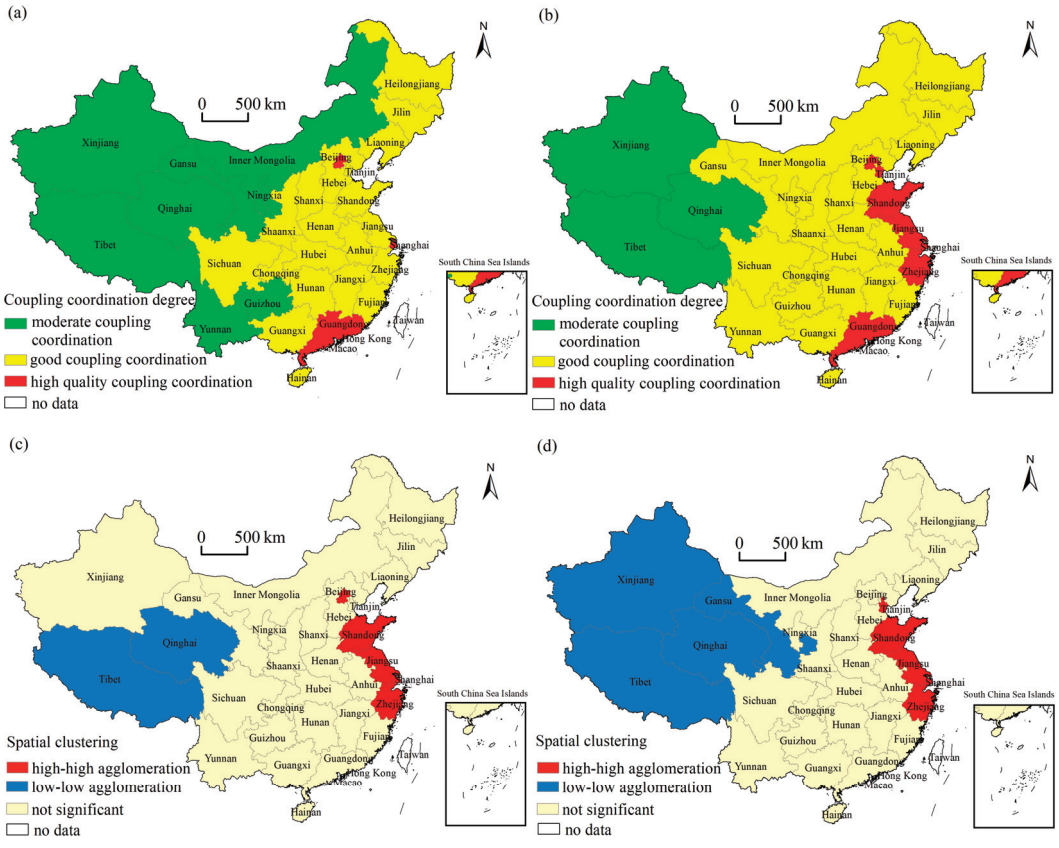


Figure 2. Spatio–temporal evolution of coupling coordination degree and spatial clustering between population health and economic development in China: (**a**) Coupling coordination degree in 2000; (**b**) Coupling coordination degree in 2015; (**c**) Spatial clustering of coupling coordination degree in 2000; (**d**) Spatial clustering of coupling coordination degree in 2015.

3.3. Analysis of the Drivers of Coupled and Coordinated Population Health and Economic Development

The coupled coordination of population health and economic development was driven by multiple factors. Based on a review of existing studies and taking into account the availability of data, we analyzed four aspects of their driving roles: natural conditions, health resources, cultural quality, and urbanization level. Natural conditions are the material basis for population health and economic development, while altitude is a fundamental element of natural conditions and directly influences physical geographic elements such as climate, which is closely related to population health [49–52] and is a key natural endowment on which economic development depends [53–55], and therefore characterizes natural conditions by mean altitude. Health resources are an important guarantee of population health, and under the current health resource allocation system, financial health expenditure largely determines the supply and functional realization of health resources. This not only directly affects economic development [56–58] but also promotes economic development through the human capital effect, consumer demand effect, and production efficiency effect [59]. Thus, the health resource status was characterized by per capita financial health expenditure. Cultural education shapes people's health perceptions and changes lifestyles and behaviors, thereby influencing population health [60,61], and it is also a human capital

element needed for economic development, characterized by the share of the population aged 6 years and older with a university degree and above. Urbanization brings changes in the lifestyle and health literacy of the population, which affects the health status of the population [62–64] and acts on economic development through the agglomeration effect of physical and human capital production factors [65–67]. Thus, the level of urbanization was characterized by the proportion of the urban population to the total population.

By using a geodetector, the *q*-value of each driven factor on the coupled coordination of population health and economic development was calculated using data from 2000 and 2015 and ranked according to the q value (Table 2). Both study time points indicate that the drivers are ranked in order of influence: urbanization level > natural conditions > cultural quality > health resources. The results of interaction factor detection (Table 3) showed that the interactions among the influencing factors were enhanced in both study time points, indicating that the synergistic role of multiple factors in driving the coupled coordination of population health and economic development was stronger than the role of a single factor, which also reflects the complexity of the driving role. In 2000, the interaction between natural conditions and health resources and the level of urbanization and health resources ranked in the top two of all six pairs of two-factor interactions, reflecting the key influence of health resource allocation on the coupling and coordination of population health and economic development in China at the beginning of this century in a context where the health care allocation system was still inadequate [68]. In 2015, the interactions between urbanization level and health resources, and natural conditions and cultural quality ranked in the top two among all six pairs of two-factor interactions, while the one-factor influence of urbanization level and natural conditions also ranked in second place according to the previous analysis, reflecting the fundamental driving role of urbanization level and natural conditions on the degree of coupling and coordination between population health and economic development.

Table 2. The detection results of driven factors for the coupling coordination degree of population health and economic development from 2000–2015.

2000		2015	
Factor Ranking	***q*-Value**	**Factor Ranking**	***q*-Value**
Urbanization level (x4)	0.599	Urbanization level (x4)	0.715
Natural Conditions (x1)	0.477	Natural Conditions (x1)	0.536
Cultural quality (x3)	0.407	Cultural quality (x3)	0.442
Health Resources (x2)	0.172	Health Resources (x2)	0.122

Table 3. The interaction detection results of driven factors for the coupling coordination degree of population health and economic development from 2000–2015.

2000		2015	
Interaction Factor	***q*-Value**	**Interaction Factor**	***q*-Value**
x1∩x2	0.905	x1∩x2	0.717
x1∩x3	0.739	x1∩x3	0.895
x1∩x4	0.789	x1∩x4	0.833
x2∩x3	0.582	x2∩x3	0.723
x2∩x4	0.876	x2∩x4	0.913
x3∩x4	0.715	x3∩x4	0.826

Note: See Table 2 for factor explanations.

The analysis based on geodetector revealed the overall influence status of each factor but could not reveal the spatial differences in the effects of each factor. A geographically weighted regression model was further introduced to dissect the status of spatial variation in the role of factors on the coordination of population health and economic development coupling. In order to eliminate the effects of order-of-magnitude differences of each factor,

the mean data of two years were first standardized for extreme differences, and then a geographically weighted regression model was established with the degree of coupled coordination between population health and economic development as the dependent variable and natural conditions, health resources, cultural quality, and urbanization level as the independent variables. The statistics of the regression results are shown in Table 4. The results show that the model R^2 reached 0.860, and the Moran's I of the residuals was 0.016 (p = 0.524), indicating that the residuals were randomly distributed in space, and the model fit better. From the mean values of regression coefficients of independent variables, under the condition of considering the spatial heterogeneity of variable relationships, overall, natural conditions and health resources were negatively correlated with coupling coordination, while cultural quality and urbanization level were positively correlated with coupling coordination, and the intensity of influence of urbanization level remains the largest.

Table 4. Statistics of GWR analysis results of driving factors for the coupling coordination degree of population health and economic development coordination.

Constants, Independent Variables	Average Value	Maximum Value	Minimum Value	Upper Quartile Value	Median Value	Lower Quartile Value	AICc	R^2
Constants	0.467	0.570	0.273	0.324	0.475	0.523		
Natural Conditions	−0.092	0.183	−0.464	−0.282	−0.089	0.068		
Health Resources	−0.121	0.029	−0.396	−0.205	−0.107	−0.036	−70.993	0.860
Cultural Quality	0.018	0.276	−0.272	−0.058	0.028	0.106		
Urbanization Level	0.465	0.764	0.105	0.275	0.477	0.632		

A map visual representation of the regression coefficients of the factors can reveal the spatial differences in their effects on the degree of coordination of population health and economic development coupling, and the results are shown in Figure 3. There was significant spatial heterogeneity in the driving effects of the factors. The role of natural conditions, i.e., altitude, was not all negative spatially; southwest, south China and the central Hunan and Jiangxi region were relatively better at overcoming the adverse effect of altitude on the coupling and coordination of population health and economic development, thus showing a positive association, while the rest of the region showed a negative association. Health resources were negatively associated with coupling coordination in the majority of provinces nationwide, indicating that the positive effect of health resources on the coupling and coordination of population health and economic development in these provinces was still not effectively played, while Xinjiang, Heilongjiang, and Jilin had relatively sufficient health resources allocated by the population due to their vast areas and sparse populations, which strongly contributed to the coupling and coordination of population health and economic development. Cultural quality was positively associated with coupling coordination mainly in the central and eastern regions, reflecting the strong influence of higher levels of cultural quality on promoting the coupled and coordinated development of population health and economy, while the western regions showed a negative association due to the relatively backward level of Cultural quality, which to some extent limited the coupled and coordinated development of population health and economy. The driving effect of urbanization level on coupling coordination was positively correlated across the country, and the correlation strength had the spatial characteristics of decreasing from south to north.

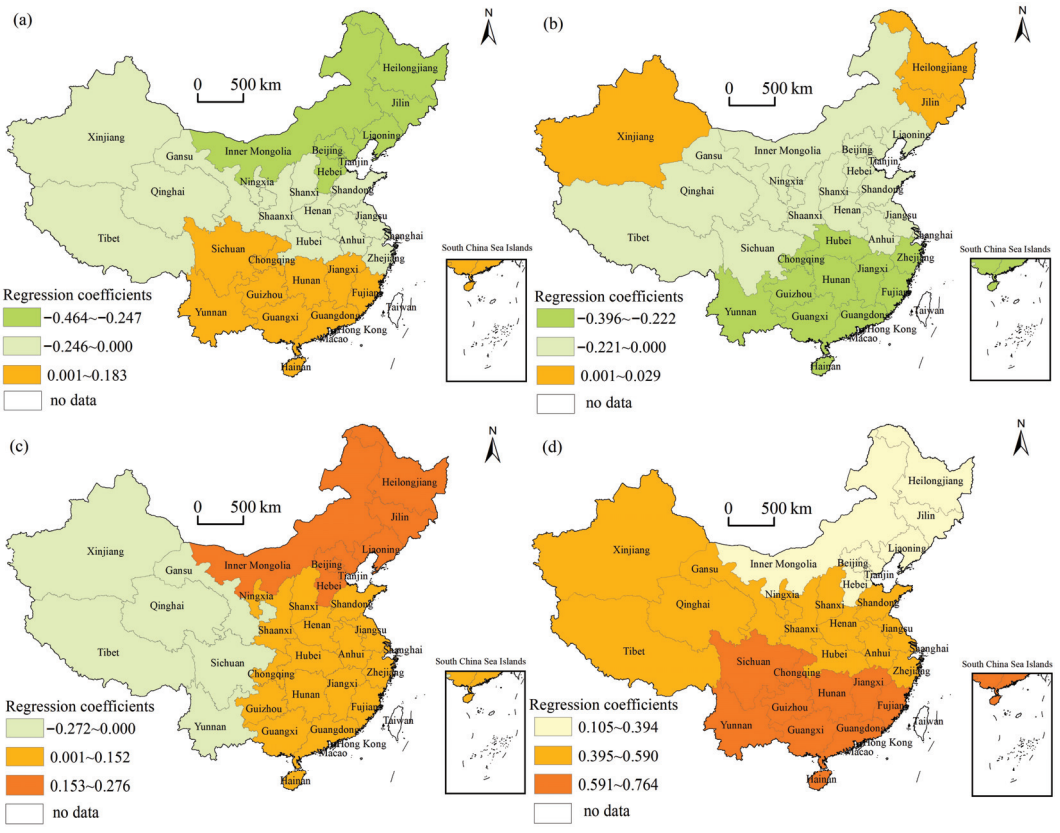


Figure 3. Spatial differences of GWR coefficients of driving factors for the coupling coordination degree of population health and economic growth: (**a**) Natural condition; (**b**) Health resources; (**c**) Cultural quality; (**d**) Urbanization level.

4. Discussion

4.1. From the Coupling Coordination Degree

Compared with existing studies, this paper finds that the coupling coordination between population health and economic development in China tends to increase over time and was influenced by multiple factors, and the influence of each factor was also characterized by interaction and spatial differences, which effectively remedied the deficiency of the current study in analyzing the coupled and coordinated status of population health and economic development in China only from a static perspective, and improved the understanding of the interrelationship between population health and economic development. Specifically, This paper shows that the coupling coordination degree of population health and economic development at the provincial scale in China in 2015 was 0.6667, which is very close to the coupling coordination degree of "Healthy China" construction and economic and social development of 0.668 calculated by Changda Li et al. [27], and although there were differences in the measurement indicators of health and economic development, both confirm that the population health and economic development at the provincial scale in China in 2015 were at the stage of good coupling and coordination. In addition, this study adds the analysis of the coupling coordination degree in 2000, which can better grasp the dynamic changes of the coupling coordination relationship and dissect the driving factors of the coupling coordination degree and its spatial differences, thus

providing a more valuable scientific basis for accurate and localized coordination of the relationship between population health and economic development.

4.2. From the Driving Factors

The analysis of the drivers of coupled and coordinated population health and economic development in China revealed that the driving influences of urbanization level, natural conditions, cultural quality, and health resources were in descending order of strength, while urbanization level and natural conditions played the main driving roles, and the synergistic driving effects of multiple factors were all greater than the single factor driving. The GWR results show that natural conditions, i.e., average altitude, were significantly negatively correlated with coupling coordination, but this effect was not absolute, and relative to higher latitudes, a few lower latitudes show a positive correlation due to their better ability to overcome the negative effects of higher altitude. Health resources, i.e., per capita financial health expenditure, were significantly negatively correlated with coupling coordination in the vast majority of provinces nationwide, suggesting that, as opposed to simply increasing the investment in health resources, optimizing the allocation of health resources is the effective measure to improve the coupling coordination between population health and economic development, especially the population allocation of health resources, which could be corroborated in the area of Inner Mongolia and Heilongjiang, which showed a positive correlation. Cultural quality was significantly and positively correlated with coupling coherence but showed opposite results in the western region. It indicates that at the national level, especially in the western region where culture and education are more backward, we should deepen the reform of the culture and education system and improve the level of culture quality of the population so as to promote the coupling of population health and economic development. The driving effect of urbanization level on coupling coordination was significantly and positively correlated across the country, and the driving effect increased gradually from north to south. It showed that increasing the level of urbanization was beneficial to the coordination of population health and economic development, which was more evident in the southern region than in the north.

4.3. Policy Suggestions

Based on the above analysis, it could be found that population health and economic development were not mutually separated and contradictory, economic development can improve health, and good health could also promote economic development, and the two were interrelated and unified. Various countries, especially developing countries, need to change the past tendency to focus on economic growth while neglecting the huge health costs caused by environmental pollution and ecological degradation and form a positive interaction between population health and economic development in order to finally achieve sustainable and high-quality development of health and economy. Meanwhile, the following policy recommendations are made to further promote the harmonious development of China's population health and the economy: First, since the coupling and coordination of population health and economic development are influenced by multiple factors, it is important to consider all the driving factors at the national level in an integrated manner and to integrate health into all policies, strengthen the top-level design and institutional safeguards based on the existing constraints of natural conditions, in terms of optimizing the allocation of health resources, deepening the reform of the culture and education system, and improving the quality of urbanization development. Second, since the factors influencing the coupling and coordination of population health and economic development have spatial differences, it is necessary to promote the coordinated development of population health and economic development at the regional level according to local conditions, especially in the western regions where coordinated development is lagging behind, and should focus on optimizing the allocation of health resources and improving population culture while trying to overcome the adverse effects of natural conditions. Third, promote the participation of multi-dimensional subjects, insist on the combination

of government-led and social and individual participation, and form a synergy to achieve coordinated development of population health and the economy.

4.4. Limitations and Future Research

The measurement of population health covers physiological, psychological, social adaptation, and other dimensions limited by the availability of data; this paper only measured the population health level from the physiological dimension, and in the future, the index system of population health level can be further improved to measure from physiological, psychological, social adaptation, and other dimensions. Furthermore, limited by the availability of data, this paper only carried out provincial-scale research, and in the future, the coupling relationship between population health and economic development can be refined and compared from provincial, municipal, and county scales, and at the same time, the scope of drivers needs to be further expanded in the future to make the research results more scientific value and policy guidance significance.

5. Conclusions

Due to the overlapping influence of multiple factors, population health has an impact on economic development, which in turn has an impact on population health, and this two-way effect is both positive and negative [24–26] and has both immediate and cumulative effects [9]. Therefore, the relationship between population health and economic development is an extremely complex proposition. From the perspective of the coupled and coordinated relationship between population health and economic development in China, this paper explores the dynamic changes and driving factors of the coupled and coordinated relationship, which is of great significance in sorting out the complex relationship between population health and economic development and promote the coordinated development between population health and economic growth. Based on the analysis of the spatial and temporal characteristics and drivers of the coupling and coordination of population health and economic development in China, the main findings include:

(1) China's population health and economic development as a whole are at a high level of coupling, and the level of coupling has slightly increased over time. Spatially, two types of coupling, running-in coupling and high-level coupling, coexist, and the coupling level tends to increase in the east and central regions, while the coupling level tends to weaken in the west.
(2) China's population health and economic development as a whole are in the stage of good coupling and coordination, and the degree of coupling and coordination has a tendency to increase. Spatially, the coupling coordination degree shows a spatial divergence characteristic of high in the east and low in the west, and the good and high-quality coupling coordination type areas tend to expand to the west, while the moderate coupling coordination type areas tend to contract to the west. There is a positive spatial clustering of population health and economic development coupling coordination, and the spatial clustering is gradually increasing.
(3) The coupled coordination of population health and economic development in China is driven by multiple factors such as natural conditions, health resources, culture quality, and urbanization level; the interaction between the drivers is stronger than the role of a single factor, and the drivers of each factor also show significant spatial heterogeneity.

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References

1. National Health and Wellness Commission of the People's Republic of China. Statistical Bulletin on the Development of Health care in China in 2019. Available online: http://www.nhc.gov.cn/guihuaxxs/s10748/202006/ebfe31f24cc145b198dd730603ec4442.shtml (accessed on 6 June 2020).
2. Song, W.J.; Li, Y.H.; Hao, Z.; Li, H.R.; Wang, W.Y. Public health in China: An environmental and socioeconomic perspective. *Atmos. Environ.* **2016**, *129*, 9–17. [CrossRef]
3. Zha, X.J.; Tian, Y.; Gao, X.; Wang, W.; Yu, C.Q. Quantitatively evaluate the environmental impact factors of the life expectancy in Tibet, China. *Environ. Geochem. Health* **2019**, *41*, 1507–1520. [CrossRef] [PubMed]
4. Bao, W.S.; Tao, R.; Afzal, A.; Dördüncü, H. Real estate prices, inflation, and health outcomes: Evidence from developed economies. *Front. Public Health* **2022**, *10*, 851388. [CrossRef]
5. Dadgar, I.; Norstrm, T. Is there a link between all-cause mortality and economic fluctuations? *Scand. J. Public Health* **2022**, *50*, 6–15. [CrossRef] [PubMed]
6. Preston, S.H. The changing relation between mortality and level of economic development. *Popul. Stud.* **1975**, *29*, 231–248. [CrossRef]
7. Harvey, B.M. Commentary: Economic growth is the basis of mortality rate decline in the 20th century—Experience of the United States 1901–2000. *Int. J. Epidemiol.* **2005**, *34*, 1214–1221. [CrossRef]
8. Wang, Z.H.; Asghar, M.M.; Zaidi, S.A.H.; Nawaz, K.; Wang, B.; Zhao, W.H.; Xu, F.X. The dynamic relationship between economic growth and life expectancy: Contradictory role of energy consumption and financial development in Pakistan. *Struct. Change Econ. Dyn.* **2020**, *53*, 257–266. [CrossRef]
9. Gong, S.S.; Chen, Y.; Zhang, T.; Zhang, Z.J. The correlation between life expectancy and GDP per capita in China from 1990 to 2010 and its changing characteristics. *Econ. Geogr.* **2020**, *40*, 23–51.
10. Hilla, T.D.; Jorgenson, A. Bring out your dead!: A study of income inequality and life expectancy in the United States, 2000–2010. *Health Place* **2018**, *49*, 1–6. [CrossRef]
11. Luo, W.; Xie, Y. Economic growth, income inequality and life expectancy in China. *Soc. Sci. Med.* **2020**, *256*, 113046. [CrossRef]
12. Mushkin, S.J. Health as an investment. *J. Political Econ.* **1962**, *5*, 129–157. [CrossRef]
13. Mayer, D. The long-term impact of health on economic growth in Latin America. *World Dev.* **2001**, *29*, 1025–1033. [CrossRef]
14. Becker, G.S.; Philipson, T.J.; Soares, R.R. The quantity and quality of life and the evolution of world inequality. *Am. Econ. Rev.* **2005**, *95*, 277–291. [CrossRef] [PubMed]
15. Arora, S. Health, human productivity, and long-term economic growth. *J. Econ. Hist.* **2001**, *61*, 699–749. [CrossRef]
16. Xu, Y.; Zeng, G.P.; Cao, Y.Q. An empirical test of the mechanisms of educational human capital, health human capital, and aggregate human capital on economic growth. *Stat. Decis. Mak.* **2018**, *34*, 109–113.
17. Yu, J.W.; Miao, Y.Q. Healthy human capital and regional economic growth in China. *J. Wuhan Univ. Philos. Soc. Sci. Ed.* **2019**, *72*, 161–175.
18. Zon, V.A.; Muysken, J. Health and endogenous growth. *J. Health Econ.* **2001**, *20*, 169–185. [CrossRef]
19. Acemoglu, D.; Johnson, S. Disease and development: The effect of life expectancy on economic growth. *J. Political Econ.* **2007**, *115*, 925–985. [CrossRef]
20. Sirag, A.; Nor, N.; Law, S. Does higher longevity harm economic growth? *Panoeconomicus* **2020**, *67*, 51–68. [CrossRef]
21. Wang, D.H.; Cui, X.Y.; Gong, L.T. The role of health in economic growth and economic development—A perspective based on literature studies. *Dyn. Econ.* **2015**, *8*, 107–127.
22. Zhang, Y.X.; Xia, J.C. How does higher healthy life expectancy promote economic growth?—An empirical study based on cross-country macro data. *Manag. World* **2020**, *36*, 41–53, 214–215.
23. Wang, J.Y.; Li, T.R. The impact of population change on the transformation of economic development mode in OECD countries. *China Popul. Sci.* **2018**, *6*, 2–16, 126.
24. Croix, D.D.L.; Sommacal, A. A theory of medical effectiveness, differential mortality, income inequality and growth for pre-industrial England. *Soc. Sci. Electron. Publ.* **2009**, *16*, 2–35. [CrossRef]
25. Qi, L.S. The interaction between economy, environment and population health: An empirical analysis based on provincial and regional panel data in China. *China Popul. Resour. Environ.* **2008**, *18*, 169–173.
26. Yu, J.Y.; Yang, Y. A study on the mutual influence of health investment, population health level and economic growth. *China Health Econ.* **2016**, *35*, 74–76.
27. Li, C.D.; Han, Y.H. Evaluation of coupling and coordination between health China construction and economic and social development. *Stat. Decis. Mak.* **2020**, *36*, 100–103.

28. Johnson, S.A. The cost of war on public health: An exploratory method for understanding the impact of conflict on public health in Sri Lanka. *PLoS ONE* **2017**, *12*, e0166674. [CrossRef]
29. Onofrei, M.; Vatamanu, A.F.; Vintil, G.; Cigu, E. Government health expenditure and public health outcomes: A comparative study among EU developing countries. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10725. [CrossRef]
30. Gong, S.S.; Chen, Y. Spatial and temporal relationships between health resources and residents' health in southern China. *Geogr. Stud.* **2020**, *39*, 115–128.
31. Chen, Y.; Wu, Y. Spatial patterns of population health levels and influencing factors in the Yangtze River Economic Zone. *Econ. Geogr.* **2020**, *40*, 152–159.
32. Murthy, U.; Shaari, M.S.; Mariadas, P.A.; Abidin, N.Z. The relationships between CO_2 emissions, economic growth and life expectancy. *J. Asian Financ. Econ. Bus.* **2022**, *8*, 801–808. [CrossRef]
33. Li, R.B.; Wang, W.Y.; Tan, J.A.; Li, H.R. Health indices of Chinese citizens and their regional differences. *Hum. Geogr.* **2004**, *3*, 64–68.
34. Fu, N.; Xiang, M.H.; Cheng, X.T. Study on factors influencing life expectancy per capita—An analysis based on data from 193 countries. *J. Popul.* **2020**, *42*, 47–56.
35. Ming, Y. Study on the trend of infant mortality rate and regional differences in China. *Popul. Res.* **2009**, *33*, 77–87.
36. Wang, L.H.; Guo, S.F.; Zhang, X.S. Analysis of the decreasing trend of maternal mortality and its related factors. *Chin. J. Perinat. Med.* **2004**, *7*, 3–7.
37. Zhou, L.; Che, L.; Sun, D.Q. The coupled and coordinated development of urbanization and economic growth in China and the influencing factors. *Econ. Geogr.* **2019**, *39*, 97–107.
38. Li, E.L.; Cui, Z.Z. Coupled and coordinated analysis of regional innovation capacity and economic development level in China. *Geoscience* **2018**, *38*, 1412–1421.
39. Department of Urban Surveys of National Bureau of Statistics. *China Statistical Yearbook*; China Statistics Press: Beijing, China, 2001–2016.
40. Department of Urban Surveys of National Bureau of Statistics. *China Statistical Abstract*; China Statistics Press: Beijing, China, 2001–2016.
41. Department of Urban Surveys of National Bureau of Statistics. *China Labor Statistical Abstract*; China Statistics Press: Beijing, China, 2001–2016.
42. Li, Q.; Zhao, Y.; Li, S.L.; Li, X.L. Analysis of the spatial and temporal characteristics and driving forces of the coupling of social security and economic development in China. *Geogr. Res.* **2020**, *39*, 1401–1417.
43. Zhao, J.J.; Liu, Y.; Zhu, Y.K.; Qin, S.L.; Wang, Y.H.; Miao, C.H. Spatial and temporal patterns and influencing factors of new urbanization and ecological environment coupling in the Yellow River Basin. *Resour. Sci.* **2020**, *42*, 159–171.
44. Zhu, J.L.; Li, Z.L. Study on the coordinated industrial-population-spatial coupling development of the Yangtze River Delta urban agglomeration. *China Popul. Resour. Environ.* **2015**, *25*, 75–82.
45. Moran, P. Notes on continuous stochastic phenomena. *Biometrika* **1950**, *37*, 17–23. [CrossRef] [PubMed]
46. Wang, J.F.; Xu, C.D. Geodetector: Principles and Prospects. *J. Geogr.* **2017**, *72*, 116–134.
47. Wang, J.F.; Li, X.H.; Christakos, G.; Liao, Y.L.; Zhang, T.; Gu, X.; Zheng, X.Y. Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun region, China. *Int. J. Geogr. Inf. Sci.* **2010**, *24*, 107–127. [CrossRef]
48. Fotheringham, A.S.; Brunsdon, C. Local forms of spatial analysis. *Geogr. Anal.* **1999**, *31*, 340–358. [CrossRef]
49. Tremblay, J.C.; Ainslie, P.N. Global and country-level estimates of human population at high altitude. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2102463118. [CrossRef]
50. Wei, C.; Lei, M.; Wang, S. Spatial heterogeneity of human lifespan in relation to living environment and socio-economic polarization: A case study in the Beijing-Tianjin-Hebei region, China. *Environ. Sci. Pollut. Res.* **2022**, *29*, 40567–40584. [CrossRef]
51. Dueñas-Espín, I.; Armijos-Acurio, L.; Espín, E.; Espinosa-Herrera, F.; Jimbo, R.; León-Cáceres, Á.; Nasre-Nasser, R.; Rivadeneira, M.F.; Rojas-Rueda, D.; Ruiz-Cedeño, L.; et al. Is a higher altitude associated with shorter survival among at-risk neonates? *PLoS ONE* **2021**, *16*, e0253413. [CrossRef]
52. Quan, X.; Guo, G.P.; Zhang, S.S.; Zhang, Y.; Liu, J.T. Trends in life expectancy changes and regional differences from 1982 to 2010 in China. *Chin. J. Gerontol.* **2017**, *37*, 6247–6250.
53. Zhao, M.; Chen, W.M.; Zhou, C.H.; Li, M.C.; Wang, N.; Liu, Q.Y. GDP spatialization and economic differences in south China based on NPP-VIIRS nighttime light imagery. *Remote Sens.* **2017**, *9*, 673. [CrossRef]
54. Zhu, F.B.; Fang, Y.P.; Yang, X.T.; Qiu, X.P.; Yu, H. Effects of altitude on county economic development in China. *J. Mt. Sci.* **2018**, *15*, 406–418. [CrossRef]
55. Zhang, B.F.; Li, J.J.; Hu, Z.Q.; Wang, J.J.; Miao, C.H. The influence of natural endowment and political region type on the economic development of Chinese counties. *Geogr. Res.* **2021**, *40*, 2508–2525.
56. Reeves, A.; Basu, S.; McKee, M.; Meissner, C.; Stuckler, D. Does investment in the health sector promote or inhibit economic growth? *Glob. Health* **2013**, *9*, 43–55. [CrossRef] [PubMed]
57. Wang, F.M. The roles of preventive and curative Health care in economic development. *PLoS ONE* **2018**, *13*, e0206808. [CrossRef]
58. Zhou, B.; Wang, S.; Qiao, Z. The relationship between "Protect people's livelihood" and "Promote the economy" provincial evidence from China. *Front. Public Health* **2021**, *9*, 722062. [CrossRef] [PubMed]

59. Tang, L.N.; Li, Y.Y.; Xi, H. Research on the impact of health expenditure on the quality of economic growth—An empirical test based on inter-provincial panel data. *East China Econ. Manag.* **2020**, *34*, 76–83.
60. Wang, C.; Wang, H.; Phillips, A. The effects of education on health and mechanisms: Evidence from China. *Appl. Econ.* **2022**, *54*, 3582–3597. [CrossRef]
61. Raghupathi, V.; Raghupathi, W. The influence of education on health: An empirical assessment of OECD countries for the period 1995–2015. *Arch. Public Health* **2020**, *78*, 95–124. [CrossRef]
62. Cheng, M.M.; Yang, H.Z. Impact of urbanization on the health status of Chinese residents—An empirical analysis based on provincial panel data. *China Popul. Resour. Environ.* **2015**, *25*, 89–96.
63. Moore, M.; Gould, P.; Keary, S. Global urbanization and impact on health. *Int. J. Hyg. Environ. Health* **2003**, *206*, 269–278. [CrossRef]
64. Miao, J.; Wu, X.G. Urbanization, socioeconomic status and health disparity in China. *Health Place* **2016**, *42*, 87–95. [CrossRef]
65. Shahbaz, M. Does trade openness affect long run growth? Cointegration, causality and forecast error variance decomposition tests for Pakistan. *Econ. Model.* **2012**, *29*, 2325–2339. [CrossRef]
66. Lin, X.Q.; Wang, D.; Ren, W.B.; Liu, Y.F. The mechanism of urbanization on economic development in China. *Geogr. Stud.* **2013**, *32*, 691–700.
67. Becker, G.S. Health as human capital: Synthesis and extensions. *Oxf. Econ. Pap.* **2007**, *59*, 379–410. [CrossRef]
68. Hu, X.Q.; Ren, J. The development and reform history of public health services in China. *China Public Health Manag.* **2019**, *35*, 339–342.

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The Relationships between Urbanization, Altitude Variability and Disaster Risk Management, Evidence from Jordan

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Abstract: This study was conducted in Jordan to assess the relationships between built environment (population growth, green surfaces, and built-up land), altitude variability, and landslide events during the period 1994 to 2020 through the application of a multi-approach investigation using statistical analyses, GIS, and remote sensing techniques. The results showed that the population densities in the study area have substantially increased. The population in the northern parts is distributed along an east–west direction that moves anticlockwise toward the south, while the southern parts population distribution is along a north–south direction that moves clockwise and to the south. The normalized difference vegetation index (NDVI) results showed that the green surfaces in the study area have decreased by 4.6%, while the built-up land density has increased. The landslide events increased from four events in 1994 to more than 20 events in 2020. There is a synchronous pattern in which the decrease in vegetation is associated with an increase in built-up land, population size, and landslide events at different altitudes, suggesting that a relationship between these factors might be present. If the current built environment practices persist, the population distribution and concentration will spread in a north-south direction along the same axis where landslide events are concentrated, posing serious future potential hazards on the population and on facilities.

Keywords: Jordan; landslide; population growth; regional planning; urban sprawl

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1. Introduction

Planning indicates, primarily, a systematic approach that addresses and explores a problem through specific objectives and methodologies [1]. Regional planning, which aims to maximize the most suitable and sustainable usage of a given physical area [2], encompasses several aspects, including land use/land cover (LU/LC) planning, where simulations of temporal and spatial changes in LU/LC can provide important insights for preparing, developing, and evaluating regional and spatial plans [3,4]; the built environment, which comprises land use, urban design, infrastructure, and human activities within a physical area [5]; and natural and human-induced hazards, with respect to which there is a tendency, on a worldwide scale, to develop improved methodologies to deal with natural disasters as part of regional planning practices, especially where settlements (urban or rural) have already been established without consideration of the natural risks in the physical area [1].

Linking these spatial patterns to population trends, natural landscapes [6], hazards, and geomorphological features has been the focus of several studies. These investigations are usually carried out using remotely sensed data and GIS techniques that can detect, map, and evaluate changes over space and time [7–11]. This approach can be related to disaster risk reduction (DRR), which comprises both hazard mitigation and regional planning DRR should be designed in a way that is oriented to a population's aptitude to manage its built environment in a manner that is adjusted to cope with the natural

and social environments [12]. The relationship between DRR and regional planning is well established. The built environment and the way it is designed can lead to disasters, especially in communities where planning policies and regulations are not usually well-enforced by local municipalities or councils [13,14].

This particularly proactive approach is referred to as "non-structural mitigation" of DRR. It is concerned with directing new built environment practices away from known and documented hazards through well-guided planning and policies, or relocating existing built environment developments toward safer areas while maintaining protective natural features, such as forests and green surfaces [15]. This approach is also in line with United Nations Sustainable Development Goal (SDG) 11, which aims at *"Making cities and human settlements inclusive, safe, resilient and sustainable"* [16], and with the Sendai Framework for Disaster Risk Reduction (2015–2030).

Built environment vulnerability and proneness to natural hazards have been the subject of several studies [14,17,18]. Changes in a built environment usually result in changes in land use [8,19] and may lead to deforestation. If not well planned, such changes may trigger natural hazards, e.g., landslides and destructive floods [19,20]. The interrelationship between landslides, built environments, population growth, and deforestation has been reported in several studies [14,21]. Holcombe et al. [14] concluded that unplanned built environments, especially in low-income communities, can lead to landslides, as urbanization and construction can have a destructive behavior toward unstable landmasses along slopes.

In Jordan, a country with a rich history of human occupation that dates back thousands of years [22], the population has increased rapidly over the past several decades, from about 230,000 in 1921 to 10,806,000 in 2020 [23], due to natural population growth and the influx of refugee [24]. This increase has decreased agricultural lands and increased unplanned built environments [8,11], adding pressure on natural resources [25]. Thus, the resulting built-environment practices and population increases in parts of Jordan are random [8,26] and haphazard, following a concentrated urban pattern rather than a pattern that is well-spread over the geographic areas [27].

One of the most important geohazards in Jordan is landslides, which are considered to be a third-priority natural disaster based on the Jordan National Natural Disaster Risk Reduction (JNDRR) Strategy (2019–2022). Several studies have concluded that landslides in Jordan are the result of the geological characteristics, tectonic settings, and morphological characteristics of the area; nonetheless, they have emphasized that anthropogenic activities have accelerated their occurrences [28–34].

This study presents new data regarding regional planning in Jordan, as reflected by changes in the built environment and its relationship with landslide events in the area between Amman and Jarash, alongside the Amman-Jarash highway, for the period 1994–2020, using satellite images, GIS, and statistical techniques. We also evaluate the relationship between geomorphological features and changes over time and space. In addition, this study provides a comprehensive geodatabase for the current built environment and social services, relative to landslide locations, to aid in the future planning in the area and to minimize the risk of future catastrophic losses in lives and property.

2. Study Area

The study area is located between the Amman and Jarash governorates (Figure 1), specifically from Jarash in the north to Mubis in the south and from Al Aluk in the east to Al Jazzaza in the west. The study area extends over parts of the Zarqa, Balqa, and Jarash governorates. The study area covers an area of approximately 270 km^2. The area comprises several landmarks, including King Talal Dam, and Wasfi Tal Forest, as well as several settlements with varying population sizes.

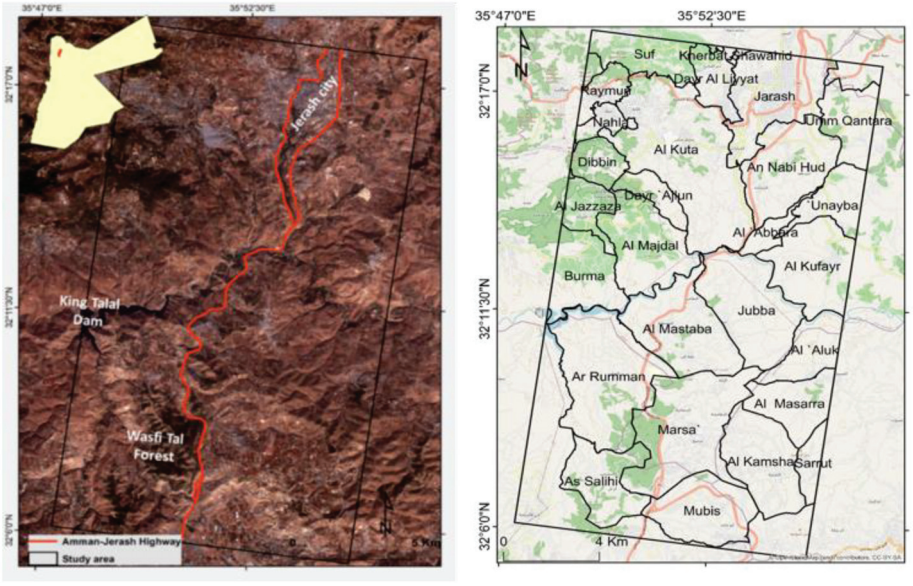


Figure 1. Left: study area location overlay a Sentinel-2 image. Image source: USGS earth explorer. Right: study area location overlay OpenStreetMap Standard Map (from https://www.openstreetmap.org/ (accessed on 15 July 2022)).

The built environment in the study area comprises built-up land, social services, green areas (forests and agricultural lands), and water bodies.

Based on data collected from the respective municipalities (Jarash and Bab Amman), the area comprises 24 settlements (Table 1). A major feature in the study area is the Amman–Jarash highway that passes through the old Amman–Syria highway (Figure 1).

Table 1. Populated settlements in the study area based on data from the respective municipaliteis and the Jordan Department of Statistics.

Admin Area	Population 2020	Admin Area	Population 2020
Jubba	5249	**Suf**	21,243
An Nabi Hud	2016	**'Unayba**	316
Al 'Abbara	227	**Al Kuta**	46,206
Al Kufayr	2788	**Raymun**	8804
Marsa'	5166	**Dibbin**	243
Ar Rumman	2250	**Jarash**	57,434
Mubis	9657	**Dayr Al Liyyat**	3253
As Salihi	1309	**Nahla**	4459
Al Mastaba	5529		
Al Majdal	491		
Sarrut	2114		
Al Kamsha	2407		
Al Jazzaza	1553		
Burma	6855		
Al 'Aluk	1365		
Al Masarra	1412		

The administrative areas represent both urban and rural settlements. The areas with more than 5000 people include Jarash City, AlKuta, Raymun, Jubba, Marsa', Mubis, Al Mastaba, and Burma, while the rest of the settlements are rural, with fewer than 5000 people.

3. Materials and Methods

The study methodology included collecting relevant literature and required datasets, as follows:

- Digital Elevation Model (DEM) SRTM v3 (30 m resolution) and satellite images (Landsat 5TM and Landsat 8OLI/TIRS) were downloaded from the USGS website (https://earthexplorer.usgs.gov/) accessed on 2 April 2021 and the Glovis website (https://glovis.usgs.gov/app) accessed on 2 April 2021.
- Administrative areas' geographical borders were obtained from the respective municipalities of Bab Amman and Jarash.
- Census data for 1994, 2004, 2015, and 2020 were downloaded from the website of the Department of Statistics in Amman, Jordan (http://dosweb.dos.gov.jo/) accessed on 26 March 2021.
- Administrative areas' (in km^2) data was obtained from the website of the Department of Statistics in Amman, Jordan (http://dosweb.dos.gov.jo/) accessed on 26 March 2021.
- Social services data were obtained from the Ministry of Education (schools), the Ministry of Health (health centers), and Civil Defense (civil defense centers) in the Jordan websites and via the use of Google Earth Pro Software.

The data was then preprocessed based on the intended analyses, tabulated, and saved in proper formats using Excel spreadsheets, shapefiles, etc. For the detailed methodologies used in this study, see Supplementary Materials File S1.

3.1. Built Environment Parameters

Together with GIS spatial analysis tools, such as choropleth maps, point density maps, heat maps, and directional distribution ellipses, which are useful in understanding the spatial and temporal variability in population size and growth rates, remote sensing (RS) data obtained through satellite remote sensing (SRS) are important in mapping different built-environment parameters [35–40].

Several indices have been developed to extract desired features and maps from RS data. Of these, the normalized difference vegetation index (NDVI) is the most widely used to extract vegetation cover [37,41,42]. In addition, built-up land can be observed and its changes can be monitored using image classification tools in ArcMap Software [8].

3.1.1. Population Size and Growth Rate: Spatial and Temporal Variations

For this component, a descriptive analytical approach was applied. The administrative boundaries data and the census data were obtained from the respective governmental directorates for the towns in the study area. The data were then tabulated and inserted into Microsoft Excel software for statistical analysis and to calculate the population growth rates. The data were then put into a GIS environment (ArcMap 10.8.1) to generate maps that showed the populations' temporal/spatial distribution, the growth rates' spatial distribution, the population density, the mean center point of population, and the directional distribution-standard deviation ellipses for 1994, 2004, 2015, and 2020.

3.1.2. Built-Up Land Changes

Following the study of Al Rawashdeh et al. [8], Landsat images were used to detect temporal and spatial changes in built-up areas and to calculate their areas and percentages over the studied time periods. Landsat data were inserted into ArcMap software and, using digital image processing tools, the built-up lands were mapped by supervised classification. The color combination of bands 4 (red), 3 (green), and 2 (blue) was used for this step. In this color combination, the built-up land appears in cyan color, while vegetation appears in red and green colors and water appears in black [41]. Because the focus is on delineating

built-up lands, the on-screen digital image processing focused the training sample points on identifying areas with cyan color. Built-up (urban) areas typically comprised industrial and commercial buildings, residential development areas, and transportation facilities [41].

3.1.3. Green Surface Changes (Using NDVI)

NDVI [41] depends on the chlorophyll absorption of visible light and the reflectance of near infrared by the plant leaves and the cellular structures. Because satellite images are composed of bands that reflect different parameters of an image collection, measuring the difference between near infrared (NIR) and red bands in a satellite image provides an indication of the presence of chlorophyll and, thus, vegetation [39,42]. In ArcMap, the images were pre-processed (Supplementary Materials File S1) and Formula (1) was applied, using the spatial analysis tool "raster calculator".

$$NDVI = NIR - RED/NIR + RED \quad (1)$$

The resultant index has values ranging from −1 to 1. Values <1 indicate water or snow; values <0.1 and >0 reflect empty areas, rocks, and sand. Values of about 0.1–0.3 indicate meadows and shrubs, while high values, >0.3, indicate vegetation [42].

For 1994 and 2004, Landsat 5 images were used, while the 2015 and 2020 NDVI calculations were based on Landsat8 imagery. The raster NDVI maps were then reclassified and the areas for the index values were calculated as pixel areas and then transformed into percentages. The NDVI maps and the calculated areas were measured for the subsequent time periods, 1994 to 2004, 2004 to 2015, and 2015 to 2020, to estimate the temporal and spatial variability in the green surfaces in the study area. Change detection in NDVI was calculated using the "Combine Tool" from the spatial analyst in ArcMap 10.8.1 software (version number 10.8.1.14362, Esri Inc., Redlands, CA, USA).

3.1.4. Social Services Mapping and Spatial Analysis for 2020

For the facilities and institutions mapping, online resources and Google Earth Software were used. The schools' data were downloaded from the Jordan Ministry of Education website [43] and mapped on Google Earth Pro 2020 software (version number 7.3.4.8642, Google Inc., Mountain View, CA, SA). The health centers' data were downloaded from the Jordan Ministry of Health website [44] and mapped on Google Earth Pro 2020 software. For the civil defense centers, data were digitized using Google Earth Pro Software. The data were then input into ArcMap 10.8.1 and transformed into shapefiles as part of a geodatabase for 2020. The data from this step were used as an input for the final map to show the present-day locations of the important social services in the study area, relative to the green surfaces, the built-up land, the population patterns, and the recorded landslides.

3.2. Landslide Spatial and Temporal Variability

To estimate landslide variability during the period from 1994 to 2020, the landslide event locations documented in the literature from 1994 to 2018 [28–31,33,34] were collected and the raw data were entered into ArcMap and transformed to shapefiles. Landslide maps were generated for 1994, 2004, and 2015. Then, the landslide events recorded in the media for 2019, 2020, and 2021 were added to the map to generate the final landslide map for 2020. A field trip was conducted to validate the 2020 landslide map, visiting the landslide locations and documenting them on the ground, using GPS readings and photographs. Finally, new landslide events were added to the map, which were located using Google Earth software and the fieldwork investigations.

3.3. Topographical Investigation

Topography plays a significant role in determining the distribution and change in land cover and population [11]. Thus, this study used DEM data and GIS techniques in order to calculate the elevation and slope in the study area. Based on the DEM data, the slope was calculated using the slope tool from the spatial analyst tools in ArcMap software.

Then, the raster data were converted to feature class (polygons) to calculate their areas and to estimate the spatial distribution of the elevation and slope. The "Union Tool" from the Arc Toolbox was then used to combine the different layers from previous analyses of the elevation (based on elevation scales used by Zreqat [11]), to investigate the effect of topography on the built-environment changes and the landslide events.

4. Results

4.1. Population Size and Growth Rates and Distribution Patterns during the Period 1994–2020

In order to better understand the population sizes, the descriptive statistics (Table 2) were calculated. The results for the study area as a whole showed that a high positive skewness (>2) was observed, which may affect any further investigations of population densities and distributions in which high values could mask smaller variations. To reduce this skewness, the study area was subdivided into two parts (northern and southern). The northern parts comprised the highest population sizes. The calculated descriptive statistics for the northern and southern parts showed lower enhanced skewness values of ~1 [45]. The population spatial and temporal analyses were conducted based on this subdivision in order to obtain better localized patterns.

Table 2. Descriptive statistics of the complete study area (northern parts and southern parts), showing better statistical parameters obtained after the study area's segmentation. POP: Population.

Study Area				
	POP_1994	POP_2004	POP_2015	POP_2020
Mean	3687.04	5194.04	7599.63	8014.42
Median	1149.5	1609	2294.5	2597.5
Skewness	2.3	2.37	2.59	2.82
Minimum	43	39	201	227
Maximum	21,278	31,652	50,745	57,434
Northern Parts				
	POP_1994	POP_2004	POP_2015	POP_2020
Mean	8500.88	12,124	17,223.13	17,744.75
Median	3699.5	4713.5	5859.5	6631.5
Skewness	0.59	0.65	0.93	1.19
Minimum	43	39	215	243
Maximum	21,278	31,652	50,745	57,434
Southern Parts				
	POP_1994	POP_2004	POP_2015	POP_2020
Mean	13,558.59	1812.41	2855.65	3226.29
Median	925	1239	1988	2250
Skewness	1.08	0.7	115	1.15
Minimum	341	326	201	227
Maximum	3725	4467	8531	9657

Population Growth Rates and Distribution Patterns

Table 3 lists the population growth rates for the settlements during the periods of 1994 to 2004, 2004 to 2015, and 2015 to 2020. The results showed that the population growth rates were not similar across the study area, probably due to unplanned practices observed in areas around Jordan [26,27], where some settlements had relatively high growth rates, while other settlements showed negative rates, probably reflecting the internal immigration effects that were common in Jordan, where people relocated to settlements with better economic potential [46]. The data showed that the main period with the highest population growth rate in the study area was from 2004 to 2015.

Table 3. Calculated population growth rates for the period from 1994 to 2020 in the study area. Note that population growth from 2015 to 2020 is based on a five-year period.

Southern Parts				Northern Parts			
Settlement	**Pop gr_94_04**	**Pop gr_04_15**	**Pop gr_15_20**	**Settlement**	**Pop gr_94_04**	**Pop gr_04_15**	**Pop gr_15_20**
Jubba	3.04	3.45	2.48	Suf	2.02	1.09	−4.69
An Nabi Hud	4.08	6.39	2.48	Unayba	0.37	12.24	2.49
Al Abbara	−0.45	−4.84	2.43	Al Kuta	5.04	4.31	0.49
Al Kufayr	3.22	3.33	2.48	Raymun	2.72	2.14	2.48
Marsa	3.11	3.79	2.47	Dibbin	−0.98	17.07	2.45
Ar Rumman	8.37	3.13	2.48	Jarash	3.97	4.72	2.48
Mubis	5.12	11.53	2.48	Dayr Al Liyyat	2.77	1.69	2.48
As Salihi	−1.67	3.9	2.49	Nahla	1.85	2.25	2.47
Al Mastaba	3.87	3.43	2.48	Average	2.22	5.69	1.33
Al Majdal	0.62	−3.5	2.47				
Sarrut	2.46	5.07	1.55				
Al Kamsha	5.05	5.4	2.48				
Al Jazzaza	1.44	1.52	2.48				
Burma	1.82	3.04	2.48				
Al Aluk	4.15	6.49	2.48				
Al Masarra	−1.31	8.69	2.49				
Average	2.68	3.8	2.42				

4.2. Built Environment and Landslide Changes (1994–2004)

Point density (heat) maps were generated for 1994 and 2004 (Figure 2). A general increase in the population size was noted, where the population increased from 1200 to 1400 and from 6800 to 10,000 people, respectively, in the southern and northern parts of the study area. The increase in population was higher in the northern parts, especially in the Jarash, Suf and Alkuta settlements, while the increase in the southern parts was mainly concentrated in Al-Mastaba, Burma, Jubba, and Mubis.

In terms of built-up land for 2004, the results (Figure 2b) indicated that built-up land covered 10.3% of the total area, a change of about 145% (Table 4) when compared to 1994 (4.2%). The increase was noted in all parts of the study area; however, it was particularly concentrated in Jarash, AlKuta in the north and central parts of the study area, around Jubba and AlMastaba, and to the south toward Amman. The built-up land and the population densities and directional distributions showed moderate similarity, probably indicating that population growth in the area was not directly linked to increases in built-up lands., such as developments in built-up lands and the resultant deforestation.

Table 4. Changes in built environment and landslide events during the period from 1994 to 2004.

Component	**Percent of Total Study Area (%)**		
	1994	**2004**	**Change (%)**
Built-up land	4.2	10.3	59.22
Green surfaces (NDVI)	16.6	16.4	−1.22
		Incidents	
Landslides	4	11	175

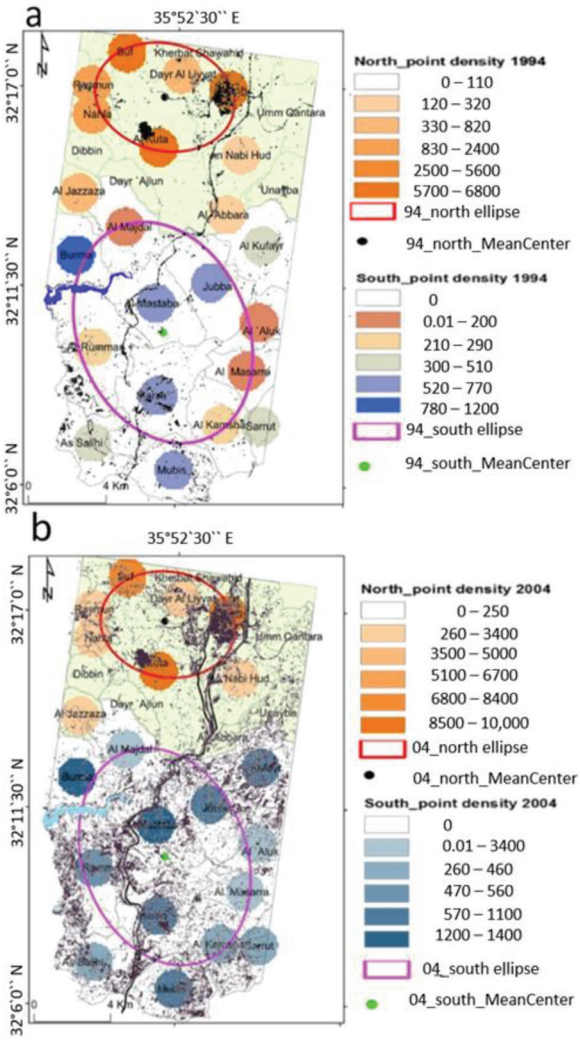


Figure 2. Heat maps (point density) showing the population concentration in the study area with the population directional distribution ellipses and the mean center points for 1994 (**a**) and 2004 (**b**). Superimposed is the built-up land map (black color).

In terms of vegetation changes, the NDVI analysis (Supplementary Materials File S2) for 1994 indicated that the green surfaces (>0.3 NDVI values) represented 16.6% of the total area (Figure S1). The values <0 that represented water that primarily reflecting the King Tala Dam. The green surfaces were primarily concentrated in Wasfi Tal Forest and in Debbin along the western and southern highlands, with some cover over the eastern parts of the study area and around the Dam and the Zarqa River. For 2004, the green surfaces covered similar areas (16.4%) (Figure S2), compared with 1994 where there was a slight decrease of −0.2% (change of −1.22%) (Table 4). The losses were primarily observed in the northern areas near Al Kuta, Jarash, and Raymun, in the central parts near AL Mastaba, and in the southern parts near As Salihi. The reduction in NDVI can be attributed to several reasons

For the landslide events, the results indicated an increase during this period. In 1994, only four landslide events were recorded in the literature. They were located in close proximity to Al Mastaba, Jubba, and Al Abbara, at elevations of 200 m asl to 500 m asl.

For 2004, the literature indicated that the landslide events increased to 11 incidents spread over a wider geographical area. The concentration of landslides was primarily within Al Mastaba and Al Abbara at the sides of the main highway. One landslide event was recorded in 2004, near Mubis in the south at an elevation of 500 m asl to 1000 m asl, while the rest of the landslides were at 200 m asl to 500 m asl. Landslide events during this time period increased by 175% (Table 4).

The built-up land distribution in 1994 was concentrated at elevations of 500 m asl to 1000 m asl (66.3%) and 200 m asl to 500 m asl (30.89%) (Table 5). Lowlands at <200 m asl comprised 1.08% of the total built-up lands, while the highlands, >1000 m asl, comprised the lowest percentage at 0.32%. These variations were also observed for the NDVI topographical distribution, where the highest NDVI percentage (>0.3 index) was concentrated at elevations of 200 m asl to 500 m asl and 500 m asl to1000 m asl with percentages of 40.95% and 35.23%, respectively. The lowest NDVI percentage was at <200 m asl, while 21.08% was detected at >1000 m asl. The lower percentages at <200 m asl might be the result of reduced precipitation rates, compared with higher elevations; the higher percentage at >1000 m asl might reflect forests at high altitudes. The concentration at 200 m asl to 1000 m asl, which was similar to built-up land concentrations, might reflect the role of agricultural activities in the study area [47].

Table 5. The influence of altitude on built-environment changes and landslide development during the period from 1994 to 2004. Built-up land and NDVI values are percentages of total index.

	Altitude (m asl)			
Built-up Land	**<200**	**200–500**	**500–1000**	**>1000**
1994	1.08	23.70	66.30	0.32
2004	1.61	30.89	74.90	1.20
Change %	49.07	30.34	12.97	275.00
NDVI				
1994	1.35	40.95	35.23	21.08
2004	17.10	30.73	24.00	25.34
Change %	1166.67	−24.96	−31.88	20.21
landslides				
1994	0.00	4.00	0.00	0.00
2004	0.00	8.00	3.00	0.00
Change %	0.00	100.00	300.00	0.00

However, in 2004 the built-environment spatial and topographical distribution varied. The built-up lands at altitudes <200 m asl increased by 49.07%; those at 200–500 m asl increased by 30.34%; those at 500 m asl to 1000 m asl, increased by 12.97%, and those at >1000 m asl increased by 275% (Table 5). The NDVI changes varied between positive and negative values, where NDVI at <200 m asl and at >1000 m asl increased by 1166.67% and 20.21%, respectively. The increase at elevations <200 m asl could be attributed to the lower Zarqa River development project (King Talal Dam) that started in 1997 ([11]), while the increase at >1000 m asl could be attributed to an increase in highland forests. On the other hand, NDVI decreased at altitudes of 200 m asl to 500 m asl and 500 m asl to 1000 m asl, by −24.96% and −31.88%, respectively. This decrease was associated with an increase in built-up land, probably reflecting the increase in population density and the associated urbanization and infrastructure construction, among other factors.

4.3. Built Environment and Landslides Changes (2004–2015)

Following the changes from 1994 to 2004, the next 11 years (2004 to 2015) showed the most distinctive changes in population trends in the study area. A substantial increase in the population size was recorded (Figure 3), with the highest average population growth

rates of 3.8% and 5.69% for the southern and northern areas, respectively. The population sizes in the study area in 2015 increased from 1400 to 2700 and from 10,000 to 16,000 in the southern and northern parts of the study area, respectively. The population was mainly concentrated in the northern Jarash, Suf, and Alkuta settlements, while the increase in the southern parts was mainly concentrated in Al-Mastaba, Burma, and Mubis.

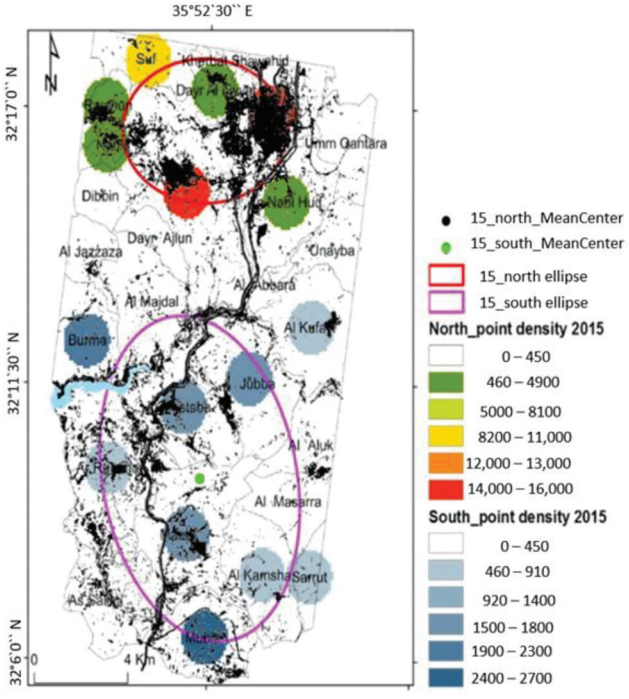


Figure 3. Heat maps (point density) showing the population concentration in the study area with the population directional distribution ellipses and mean center points for 2015. Superimposed is the built-up land map (black color). For the admin area borders and names refer to Figure 2b.

In terms of built-up land in 2015, the results showed that built-up land represented 14.34% of the total study area (Figure 3). The built-up land development was concentrated in Jarash, Alkuta, Raymun, and Debbin in the northern parts of the study area and to the southeast of Jarash in Nabi Hud, while it was concentrated in Al Mastaba, Jubba, Marsa', Ar Rumman, and Mubis in the southern parts, with increased built-up lands toward Amman and around King Talal Dam. In contrast with the observations for the period from 1994 to 2004, the built-up land and population densities showed good agreement where the built-up land primary concentrations were located within the population directional distribution ellipses, suggesting that population growth for this period was directly linked to increases in built-up lands.

The NDVI analysis (Supplementary Materials File S2) for 2015 indicated that the green surfaces (>0.3 NDVI values) represented 12.8% of the total area (Figure S4). The green surfaces were primarily concentrated in Wasfi Tal Forest and Debbin, along the eastern and southern highlands, with some cover over the eastern parts of the study area and around the Zarqa River. A decrease of 3.6% of the total green surface area was noted in the central and northern parts of the study area (Figure 4). This reduction accounted for a change of −21.95%. The results (Figure 4) showed that the losses in NDVI were primarily observed in the northern areas near Al Kuta, Jarash, An Nabi Hud, in the central parts near AL Mastaba, Jubba, Al Mastaba, and Marsa', and in the southern parts near As Salihi.

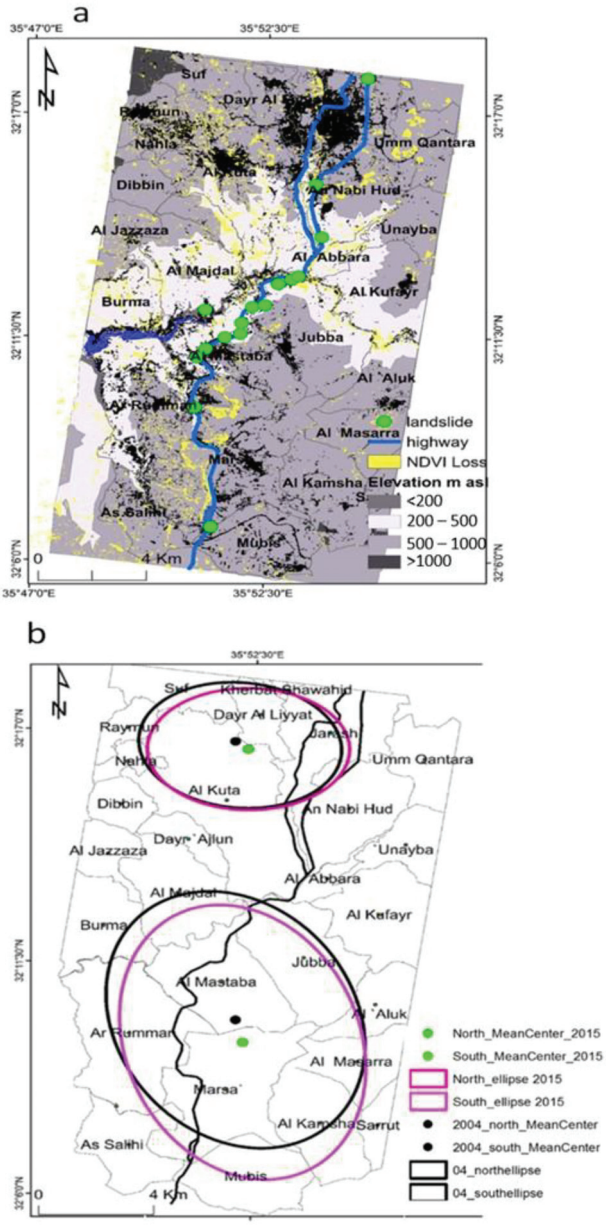


Figure 4. (**a**) Synthesis map showing the built-environment components, black: built-up land in 2015, yellow: NDVI loss. For the admin area borders and names refer to b; (**b**) illustration of the changes in population directional distribution and mean center points during the 11 years from 2004 to 2015.

Regarding landslide events, 16 locations were recorded in the literature for 2015 (Figure S5). The events were located close to Al Mastaba, Jubba, and Al Abbara. The concentration was primarily within Al Mastaba and Al Abbara at the sides of the main highway. One new event was recorded in the northern parts near Jarash. The landslides were found at altitudes of 200 m asl to –500 m asl and 500 m asl to 1000 m asl. Changes

were observed at 200 m asl to 500 m asl. Additionally, one new event was recorded at <200 m asl. Landslide events during this time period increased by 45.45% (Table 6).

Table 6. Changes in built environment and landslide events during the period from 2004 to 2015.

Component	Percent of Total Study Area (%)		
	2004	**2015**	**Change (%)**
Built-up land	10.3	14.34	39.22
Green surfaces (NDVI)	16.4	12.8	−21.95
		Incidents	
Landslides	11	16	45.45

The built-up land distribution in 2015 in the study area was particularly concentrated at elevations of 500 m asl to 1000 m asl (54%) and 200 m als to 500 m asl (43.3%) (Table 7). Lowlands <200 m asl showed increased built-up area compared to 2004 and accounted for 5.4% of the built-up lands (total change of 235.4%), while the highlands >1000 m asl did not show significant changes (total change of 8.33%).

Table 7. The influence of elevation on built-environment changes and landslides development during the period from 2004 to 2015.

	Elevation (m asl)			
Built-Up Land	**<200**	**200–500**	**500–1000**	**>1000**
2004	1.61	30.89	74.9	1.2
2015	5.4	43.3	54	1.3
Change %	235.40	40.17	−27.90	8.33
NDVI				
2004	17.1	30.73	24	25.34
2015	25.5	28.6	21.8	24.7
Change %	49.12281	−6.93134	−9.16667	−2.52565
landslides				
2004	0	8	3	0
2015	1	13	3	0
Change %	100	62.5	0	0

4.4. Built Environment and Landslides Changes (2015–2020)

The period from 2015 to 2020 generally showed a slight change in population trends in the study area (Figure 5), with an average population growth rate of 2.42% and 1.33% for the southern and northern areas, respectively. The population sizes in the study area in 2020 (Figure 5) increased from 2700 to 3100 and from 16,000 to 18,000, respectively, in the southern and northern parts of the study area. The population was mainly concentrated in the northern Jarash and Alkuta settlements, while the increase in the southern parts was mainly concentrated in Al-Mastaba, Burma, and Mubis. In addition, based on the directional distribution and the mean center points of the population compared with those of 2015, no change in the southern parts was observed, while in the northern parts the concentration increased toward Jarash and AlKuta, moving the directional distribution in an anticlockwise movement to the southeast around the city of Jarash and the main highway (Figure 5).

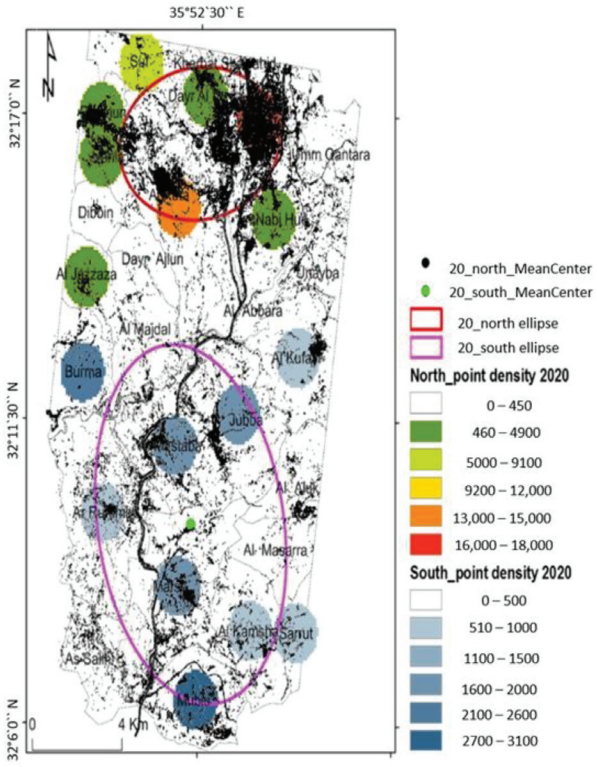


Figure 5. Heat map (point density) showing the population concentration in the study area with the population directional distribution ellipses and mean center points for 2020. Superimposed is the built-up land map (black color). For the admin area borders and names refer to Figure 4b.

For 2020, the results showed that built-up lands represented 18% of the total study area. The built-up lands (Figure 5) were concentrated in Jarash, Alkuta, and Raymun in the northern parts of the study area and to the southeast of Jarash in Nabi Hud, while they were concentrated in Al Mastaba, Jubba, Marsa', Ar Rumman, and Mubis in the southern parts, with increased built-up lands toward Amman and around King Talal Dam. The built-up land generally increased in most of the study area.

As was the case from 2004 to 2015, the built-up lands and the population densities from 2015 to 2020 showed good agreement where the built-up land concentrations were located within the population directional distribution ellipses, suggesting that population growth during this period was directly linked to increases in built-up lands.

The NDVI analysis for 2020 (Supplementary Materials File S2) (Figure S6) showed that the green surfaces (>0.3 NDVI values) represented 12% of the total area. The green surfaces were primarily concentrated in Wasfi Tal Forest and Debbin, along the eastern and southern highlands, with some cover over the eastern parts of the study area and around the dam and the Zarqa River. The decrease of 0.8% of the total green surface area represented a change of −6.2%. The results (Figure 6) showed that the losses were primarily in the northern areas near Al Kuta, in the north-western highlands, in the central parts near AL Mastaba, Jubba, and in the southern parts near Marsa'. The reduction in NDVI indicated reduced green surfaces in the resultant locations, which can be attributed to several factors, such as developments of built-up lands and the resulting deforestation.

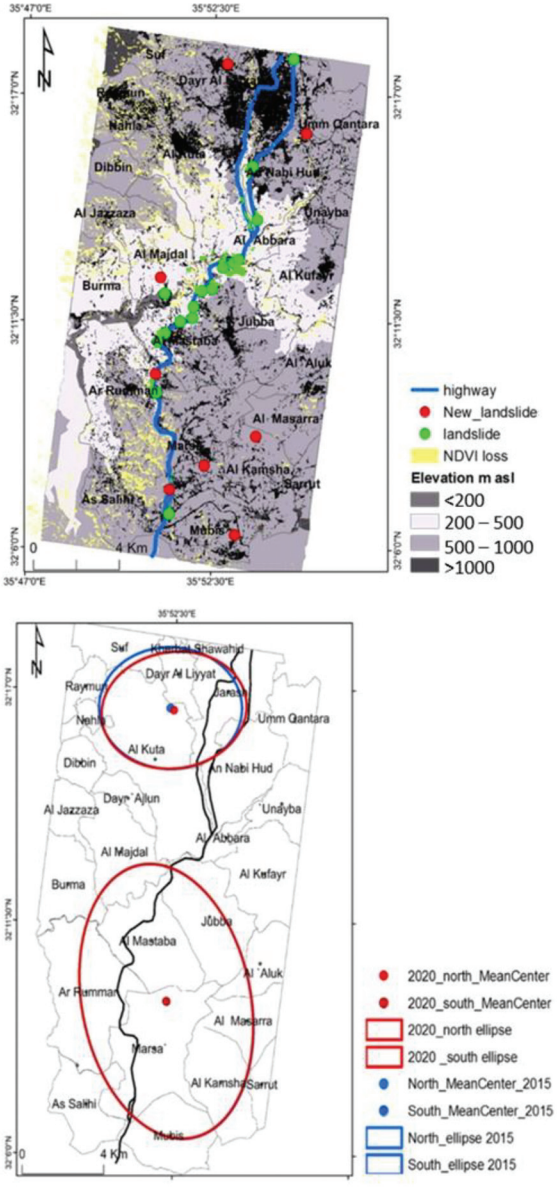


Figure 6. Top: synthesis map showing the built environment components. Black: built-up land 2020. For the admin area borders and names refer to bottom. Bottom: illustration of the change in population directional distribution and mean center points in the study area during the period from 2015 to 2020.

During the period from 2015 to 2020, six new landslide locations were recorded in the literature (Figure S7). However, it is worth mentioning that the previous studies focused on investigating landslide events at the sides of the main highway and did not provide comprehensive investigations of the complete study area.

Using GE Software and fieldwork, new landslide events were recorded away from the main highway (Figures S7 and S8). The landslide events were primarily concentrated

at altitudes of 200 m asl to 500 m asl and 500 m asl to 1000 m asl, while few events were recorded at lower altitudes, <200 m asl, following recent built-up land increases in the lower altitudes. Nonetheless, the main location where landslide events were recorded was the central area of the study, close to Al Mastaba, Jubba, and Al Abbara. Another area of interest was the southern part, where new landslide events were recorded in this study and where populated areas were present. Because the landslide events recorded in this study may not be representative of the period from 2015 to 2020 and the fact that they may have been present for longer periods, only three landslides located close to the main highway and the one at <200 m asl were considered, with the landslide locations from the literature, in the change calculations.

The built-up land distribution in the study area in 2020 was particularly concentrated at elevations of 500 m asl to 1000 m asl (64%) and 200 m asl to 500 m asl (25.1%) (Table 8). Lowlands, <200 m asl, showed increased built-up areas compared with 2015 and accounted for 13% (a total change of 140.7%), while the highlands, >1000 m asl, showed negative changes (a total change of −46%).

Table 8. The effect of elevation on built-environment changes and landslide development during the period from 2004 to 2015.

	Elevation (m asl)			
Built-up Land	**<200**	**200–500**	**500–1000**	**>1000**
2015	5.4	43.3	54	1.3
2020	13	25.14	64	0.7
Change %	140.74	−41.94	18.52	−46.15
NDVI				
2015	25.5	28.6	21.8	24.7
2020	19.6	30.4	25.13	28.85
Change %	−23.1373	6.293706	15.27523	16.80162
landslides				
2015	1	13	3	0
2020	1	21	3	
Change %	100	61.54	0	0

5. Discussion

During the studied time period from 1994–2020, the population densities varied, resulting in changed urban and rural settlements in the study area. The area's population size increased from 88,489 people in 1994 to 192,346 people in 2020, a total change of 117.4%. Similar to other areas in Jordan [11,27,48,49], the population distribution in the study area has not been well-planned; it is unequal in terms of the spatial distribution, with more than 50% of the total population concentrated in about 25% of the total physical area (Figure 7). It has been reported for Amman, Jordan [49], and Asfahan, Iran [50], that in main cities, rapid urbanization can be influenced by the presence of either main roads or agricultural lands. Similarly, this study showed that the population distribution of the study area is generally expanding near the main highway, which indicates the significance of the main highway in attracting people to the area. In addition, the population seems to be moving toward the main cities in the north and south, closer to Jarash and Amman, respectively. Considering the long-term direction of the population distribution, clockwise and anticlockwise in the southern and northern parts of the study area, respectively, the population distribution ellipse is expected to lie along the same north–south axis and to concentrate near the main highway in the future (Figure 7), if these practices are not managed.

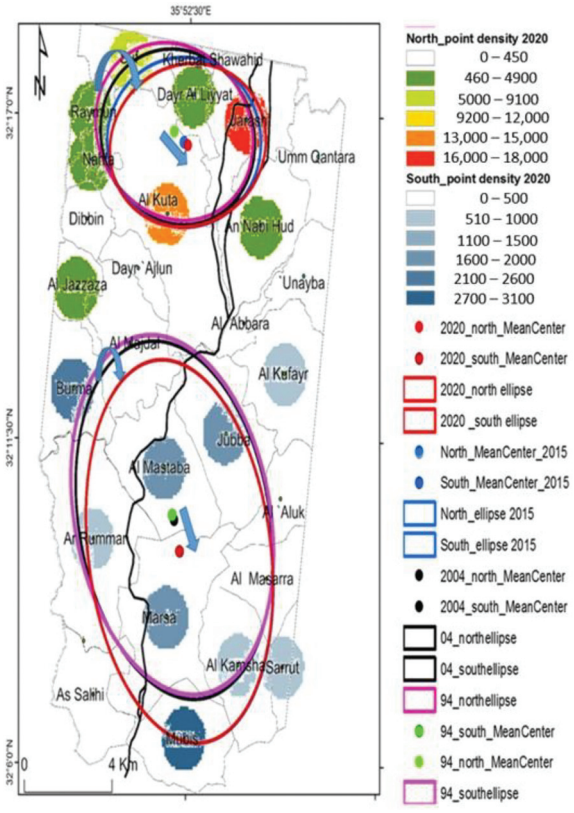


Figure 7. Map illustrating the comprehensive change in population dynamics for the period from 1994 to 2020.

Land use planning is essential in building cities that are resilient against present and potential natural risks [51]. It has been reported in different regions around the world that urbanization can be a major driver of natural hazards. In Sierra Leone, Cui et al. [20] reported that unplanned urbanization in environmentally vulnerable areas led to a destructive landsliding incident that resulted in more than 500 deaths. Similarly, temporal and spatial associations have been linked to population dynamics, built-up land increases, NDVI decreases, and the development of landslides in the study area. The results for the period from 1994 to 2004 indicate that the most significant changes in land cover (built-up land and green surfaces) in the study area took place at altitudes of 200 m asl to 1000 m asl. There were also increases in landslides at altitudes of 200 m asl to 500 m asl and 500 m asl to 1000 m asl, by 100% and 300%, respectively (Figure S3), suggesting that the built environment was probably a major factor in landslide occurrences during this period. Built-up lands substantially increased in Jarash, Suf, Al Kuta, Al Mastaba, Burma, Jubba, and Mubis. This increase was associated with a decrease in NDVI index values, emphasizing the relationship between the built environment and the natural environment and suggesting that the built environment played a significant role in the development of landslides in the area during this period. Unlike the situation in 2004, in 2015, a negative change occurred in built-up lands at altitudes 500 m to 1000 m, which probably reflected the tendency during this period toward agricultural activities at lower altitudes closer to irrigation water resources, such as the Zarqa River and King Talal Dam, which contributed to the increase in built-up lands at lower altitudes. These variations were also observed for NDVI topographical distribution, where the highest NDVI percentage for 2015 was

concentrated at elevations of 200 m asl to 500 m asl and at <200 m asl, with percentages of 28.6% and 25.5%, respectively. The lowest NDVI percentage was at 500 m asl to 1000 m asl, while 24.7% was detected at >1000 m asl. The increase in NDVI percentages at <200 m asl supports the suggestion of the tendency toward agricultural activities in lower areas. This is also supported by a negative change in NDVI between 2004 and 2015 at altitudes of 200 m asl to >1000 m asl.

In 2020, a negative change was noted in built-up lands at altitudes 200 m asl to 500 m asl, probably reflecting the tendency during this period toward built-up land changes at lower and higher altitudes. These variations were also observed for the NDVI topographical distribution, where the highest NDVI percentage for 2020 was concentrated at elevations of 200 m asl to 500 m asl and >1000 m asl, with percentages of 30.4% and 28.85%, respectively. The lowest NDVI percentage was at <200 m asl, while 25.13% was detected at 500 m asl to 1000 m asl. The increase in NDVI percentages at altitudes higher than 200 m asl probably reflected the growing season effect, as the Landsat images that were used were downloaded between May and June. A negative change in NDVI was recorded for the altitudes higher than 200 m asl, with a total change of −23.13%. The landslide events were primarily concentrated at altitudes of 200 m asl to 500 m asl and 500 m asl to 1000 m asl, while few events were recorded at altitudes lower than 200 m asl, following a recent increase in built-up land in the lower altitudes, resulting in an NDVI increase of 56.25%.

Current State of the Study Area

Social services planning is considered to be one of the primary objectives of regional planning [52]. This study analyzed the spatial planning practices of health centers, government schools (social services), and civil defense centers (administrative services) in the study area.

Based on data acquired from the Jordan Ministry of Education, the study area comprised 110 government schools (Figure S9). The schools included elementary level, secondary level, and high schools. The average nearest neighbor tool in ArcMap was used to investigate the schools' distribution patterns. The results indicated that the schools' nearest neighbor ratio was 0.512, with a z-score of −9.8 and a p value of <0.01. Considering the z-score, the schools distributio'n pattern was considered as clustered. This agrees with the unequal spatial distribution of the population, as discussed earlier. Most of the schools are located at 500 m asl to 1000 m asl, while few are located in the 200 m asl to 500 m asl altitude regions. It is noted that the density of schools (number of schools in one physical area) follows the population density, where more schools are spatially located in urban settlements with >5000 people (e.g., Jarash, Suf Al Mastaba), while fewer schools are found in rural settlements with <5000 people (e.g., Al Aluk, Al Kufayr). Most of the schools are located at slopes with values of 8% to 20%; a few schools are located at slope ranges of 21% to 55%, and others are located at slope ranges of 3% to 7%. This is significant, considering that the landslide events in the study area were found primarily at altitudes of 200 m asl to 500 m asl and to lesser extent at 500 m asl to 1000 m asl and at <200 m asl. In addition, the landslides were found at slopes >21%.

For the health services (Figure S10), the results indicated that the nearest neighbor ratio was 1.299 with a z-score of 3.02 and a p value of <0.01. Considering the z-score, the health services distribution pattern was considered as dispersed. This agreed with the unequal spatial distribution of the population densities and the distances between settlements in the study area. The health centers are located at 500 ma asl to 1000 m asl. It is noted that the density of health services follows the population density, where more services are spatially located in urban settlements with >5000 people (e.g., Jarash, Suf Al Mastaba), while less are found in rural settlements with <500 people (e.g., Al Aluk, Al Kufayr). Most of the health services are located at slopes with values of 8% to 20%; a few are located at slope ranges of 21% to 55% and others are located at slope ranges of 3% to 7%.

Based on the GE Software survey, the study area included four civil defense departments (Figure S11). The departments were located at elevations of 500 m asl to 1000 m asl

and at slope ranges of 8% to 21%. The distribution shows that they were concentrated in the northern parts of the study area, close to vegetated zones and the main cities of Jarash and Suf. Their locations indicated that they were located far from recorded landslide events. Their distribution probably followed the main population densities that were higher in the northern parts.

A comprehensive map illustrating the temporal and spatial changes in the population directional distribution and mean center points, the current built-environment components, and the landslide events in the study area was created (Figure 8) in order to assess the current planning practices and to draw on the relationship between these practices and the natural hazard locations in assessing the role of regional planning in monitoring built-environment changes and reducing natural hazard risks to ensure safer and more sustainable cities and settlements. The results indicate that the built-up environment practices in the study area are not well-planned in terms of the consideration of natural risks (e.g., landslides) and their potential hazardous impacts. As observed by the changes in built-up lands based on altitude, changes took place during periods when national projects were in operation, indicating that the economic factor is significant in driving these changes. In addition, the results indicated that the reduction in NDVI is associated with increased built-up lands in different areas, suggesting that urbanization is causing deforestation in the study area. The results also proved that whenever the built-up land increased, landslide events occurred, at certain times associated with a reduction in NDVI. This study agrees with previous studies that reported significant built-up and land cover changes in Jarash [11], Burma [48], and Amman [41,49], where significant built-up land development was recorded, and with a study [33] that provided a detailed map of zones that are highly susceptible to landsliding along the Amman–Jarash Highway.

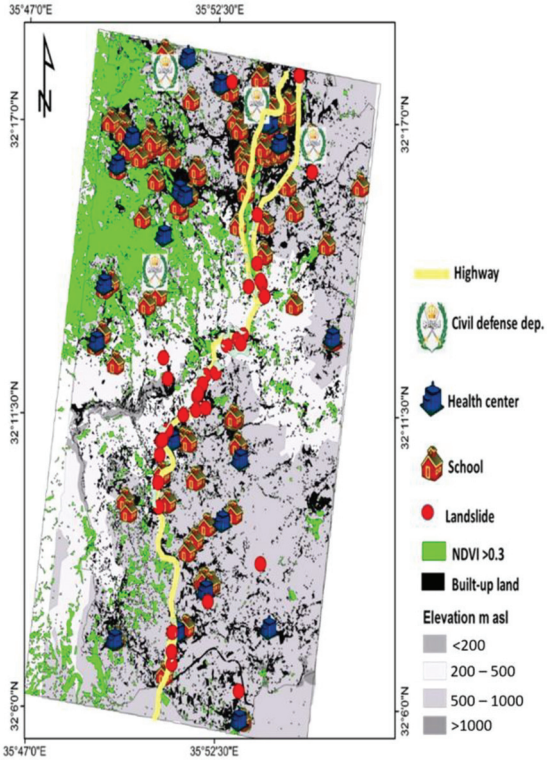


Figure 8. Comprehensive current state of the study area showing the built-environment components and the landslide locations for 2020.

6. Summary and Conclusions

The results of this study indicate the need for better regional (spatial) planning practices in the study area, in which the occurrence of natural hazards and the most susceptible altitudes and slopes would be considered in the planning of population distribution, future built-up land developments, services, and the development of green surfaces. The results provide support for decision-makers and scientific evidence that can be applied to future regional planning in the study area.

It is suggested that the built-up environment in the southern parts of the study area be planned and moved in an east–west direction rather than in a north–south direction, while considering the slope and altitude distribution in the study area and avoiding high slopes that are susceptible to landslides. It is suggested that in the northern parts of the study area, the built environments and the population distributions be planned away from landslide concentration areas and from the highway. In addition, it is suggested that the main highway should attract populations along its sides, as it offers good economic potential. Public awareness about settling close to such highway areas is also crucial in achieving more resilient and safer settlements and more effective regional planning strategies.

These observations indicate the significance of regional planning in monitoring and studying temporal and spatial changes in the built environment and linking these changes to natural hazards, a concept that is not well-practiced as part of regional planning in Jordan.

For example, based on data from the Jordan General Budget Department (GBD) [53], the following four projects have been approved for the Jarash governorate: (1) the construction and reconstruction of farm roads in Jarash, with a projected cost of JOD 3,000,000; (2) the construction and enhancement of the main and secondary village roads, with a projected cost of JOD 1,400,000; (3) the rehabilitation of the forested lands in Jarash, with a projected cost of JOD 150,000; and (4) the rehabilitation of 30% of the Debbin natural forest areas that are subject to fire hazards, with a projected cost of JOD 30,000. The planning processes for these projects should include consideration of the outcomes of this study, and include natural hazards as part of infrastructure planning and as a guide in identifying the areas with the most suitable and urgent needs for vegetation.

Supplementary Materials: Supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14159241/s1, File S1. Detailed Methodology of the Study [11,28–42,54–58]. File S2. Detailed Maps of the Study: Figure S1. NDVI map of the study area for the year 1994. Figure S2. NDVI map of the study area for the year 2004. Figure S3. Landslide locations for the years 1994/2004 (for data sources see the main text), superimposed on DEM data. Figure S4. NDVI map of the study area for the year 2015. Figure S5. Landslide locations for the year 2015 (for data sources see the main text), superimposed on DEM data. Figure S6. NDVI map of the study area for the year 2020. Figure S7. Landslide locations for the year 2020 (for data sources see the main text), superimposed on DEM data. Figure S8. New Landslide (NL) 5 and 6 events recovered from the fieldtrip and Google Earth survey. Also showing the landscape change over a period of 10 years (2010–2020). Figure S9. Schools spatial distribution in the study area and population densities superimposed on the DEM. Figure S10. Left: Health Centers spatial distribution in the study area superimposed on the DEM. Right: Health Centers spatial distribution in the study area and landslide locations superimposed on the slope map. Figure S11. Left: Civil Defense departments spatial distribution in the study area superimposed on the DEM. Right: Civil Defense departments' spatial distribution in the study area and landslide locations superimposed on the slope map.

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References

1. Gonzalez-Mathiesen, C.; March, A. *Developing Guidelines for Increasing the Resilience of Informal Settlements Exposed to Wildfire Risk Using a Risk-Based Planning Approach*; Santos, P.P., Chmutina, K., Meding, J., Von Raju, E., Eds.; Understanding Disaster Risk; Elsevier: Amsterdam, The Netherlands, 2021; pp. 159–178.
2. Eggenberger, M.; Partidário, M.R. Development of a framework to assist the integration of environmental, social and economic issues in spatial planning. *Impact Assess. Proj. Apprais.* **2000**, *18*, 201–207. [CrossRef]
3. Hietel, E.; Waldhardt, R.; Otte, A. Analyzing land-cover changes in relation to environmental variables in Hesse, Germany. *Landsc. Ecol.* **2004**, *19*, 473–489. [CrossRef]
4. Koomen, E.; Koekoek, A.; Dijk, E. Simulating Land-use Change in a Regional Planning Context. *Appl. Spat. Anal. Policy* **2011**, *4*, 223–247. [CrossRef]
5. Handy, S.L.; Boarnet, M.G.; Ewing, R.; Killingsworth, R.E. How the built environment affects physical activity: Views from urban planning. *Am. J. Prev. Med.* **2002**, *23*, 64–73. [CrossRef]
6. Brookes, C.J. A genetic algorithm for designing optimal patch configurations in GIS. *Int. J. Geogr. Inf. Sci.* **2001**, *15*, 539–559. [CrossRef]
7. Harris, P.M.; Ventura, S.J. The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogramm. Eng. Remote Sens.* **1995**, *61*, 993–998.
8. Al Rawashdeh, S.; Saleh, B. Satellite Monitoring of Urban Spatial Growth in the Amman Area, Jordan. *J. Urban Plan. Dev.* **2006**, *132*, 211–216. [CrossRef]
9. Al-Habees, M. Spatial Development Disparity in Jordan. *Jordan J. Soc. Sci.* **2011**, *4*, 180–202.
10. Btoush, N. Recent Trends of Population Growth and their Consequences in Jordan. *Jordan J. Soc. Sci.* **2012**, *5*, 11–124.
11. Zreqat, D. Land Cover Change in Jerash Governorate between (1952–2009) Using Geographic Information Systems (GIS) and Remote Sensing (RS). *Jordan J. Soc. Sci.* **2014**, *7*, 60–81.
12. Wamsler, C. Managing urban risk: Perceptions of housing and planning as a tool for reducing disaster risk. *Glob. Built Environ. Rev.* **2004**, *4*, 11–28.
13. Ofori, G. Construction Industry Development for Disaster Prevention and Response. In Proceedings of the i-Rec Conference on Improving Post-Disaster Reconstruction in Developing Countries, Montreal, QC, Canada, 23–25 May 2002; pp. 1–21.
14. Holcombe, E.A.; Beesley, M.E.W.; Vardanega, P.J.; Sorbie, R. Urbanisation and landslides: Hazard drivers and better practices. *Proc. Inst. Civ. Eng. Civ. Eng.* **2016**, *169*, 137–144. [CrossRef]
15. Godschalk, R. Urban Hazard Mitigation: Creating Resilient Cities. *Nat. Hazards Rev.* **2003**, *4*, 136–143. [CrossRef]
16. United Nations. *The 2030 Agenda and the Sustainable Development Goals: An Opportunity for Latin America and the Caribbean (LC/G. 2681-P/Rev. 3)*; United Nations: New York, NY, USA, 2018.
17. Wisner, B.; Blaikie, P.; Cannon, T.; Davis, I. *At Risk: Natural Hazards, People's Vulnerability and Disasters*, 2nd ed.; Routledge: London, UK, 2003; p. 496.
18. Smyth, C.G.; Royle, S.A. Urban landslide hazards: Incidence and causative factors in Niteroi, Rio de Janeiro state, Brazil. *Appl. Geogr.* **2000**, *20*, 95–118. [CrossRef]
19. Li, G.; Lei, Y.; Yao, H.; Wu, S.; Ge, J. The influence of land urbanization on landslides: An empirical estimation based on Chinese provincial panel data. *Sci. Total Environ.* **2017**, *595*, 681–690. [CrossRef] [PubMed]
20. Cui, Y.; Cheng, D.; Choi, C.E.; Jin, W.; Lei, Y.; Kargel, J.S. The cost of rapid and haphazard urbanization: Lessons learned from the Freetown landslide disaster. *Landslides* **2019**, *16*, 1167–1176. [CrossRef]
21. Chen, Y.; Xie, W.; Xu, X. Changes of Population, Built-up Land, and Cropland Exposure to Natural Hazards in China from 1995 to 2015. *Int. J. Disaster Risk Sci.* **2019**, *10*, 557–572. [CrossRef]
22. Patai, R. *Kingdom of Jordan, Princeton Legacy Library*; Princeton University Press: Princeton, NJ, USA, 2015.
23. Jordan Department of Statistics. 2020. Census report. Available online: www.dos.gov.jo (accessed on 26 March 2021).
24. Alhusban, A.; Alhusban, S.; Al-Betawi, Y. Assessing the impact of urban Syrian refugees on the urban fabric of Al Mafraq city architecturally and socially. *Int. J. Disaster Resil. Built Environ.* **2019**, *10*, 99–129. [CrossRef]
25. Salameh, E. Over-exploitation of groundwater resources and their environmental and socio-economic implications: The case of Jordan. *Water Int.* **2008**, *33*, 55–68. [CrossRef]
26. Alnsour, J.; Meaton, J. Factors affecting compliance with residential standards in the city of Old Salt, Jordan. *Habitat Int.* **2009**, *33*, 301–309. [CrossRef]

27. Quteishat, R.; Abu Sabha, K. Analyzing the Spatial Distribution of Jordanian Cities Using GIS. *Dirasat* **2014**, *41*, 529–554.
28. Malkawi, A.I.H.; Taqieddin, S.A. Geotechnical study of landslides resulting from a highway construction in Jordan. *Nat. Hazards* **1996**, *13*, 1–15. [CrossRef]
29. Mansour, Z.; Mustafa, H.; Abederahman, N. Geological and geotechnical studies of three main slides along Jerash–Amman highway. *Abhath AlYarmouk Pure Sci. Eng.* **1997**, *6*, 79–104.
30. Malkawi, A.; Saleh, B.; Al-Sheriadeh, M.; Hamza, M. Mapping of landslide hazard zones in Jordan using remote sensing and GIS. *J. Urban Plan Dev.* **2000**, *126*, 1–17. [CrossRef]
31. El-Naqa, A.; Abdelghafoor, M. Application of SINMAP terrain stability model along Amman–Jerash–Irbid highway, North Jordan. *Electron J. Geotech. Eng.* **2006**, *11*, 2–19.
32. Akawwi, E.; Al Assaf, A.; Barghouthi, A. Landslide, Rockfall Hazard Assessment and Risk Inventory Maps at South Jordan. *Int. J. Adv. Mech. Civ. Eng.* **2018**, *5*, 58–61.
33. Awawdeh, M.M.; ElMughrabi, M.A.; Atallah, M.Y. Landslide susceptibility mapping using GIS and weighted overlay method: A case study from North Jordan. *Environ. Earth Sci.* **2018**, *77*, 732. [CrossRef]
34. Masannat, Y.M. Landslide Hazards: Geotechnical Aspects and Management Policies. *Jordan J. Civ. Eng.* **2014**, *8*, 22. [CrossRef]
35. Lillesand, T.M.; Kiefer, R.W.; Chipman, J.W. *Remote Sensing and Image Interpretation*; John Wiley & Sons: Hoboken, NJ, USA, 2004.
36. Cyr, J.F.S. At risk: Natural hazards, people's vulnerability, and disasters. *J. Homel. Secur. Emerg. Manag.* **2005**, *2*, 1–7.
37. Jensen, J.R. *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd ed.; Prentice Hall: Upper Sadle River, NJ, USA, 2006.
38. Xu, H. A new index for delineating built-up land features in satellite imagery. *Int. J. Remote Sens.* **2008**, *29*, 4269–4276. [CrossRef]
39. Griffiths, P.; Hostert, P.; Gruebner, O.; van der Linden, S. Mapping megacity growth with multi-sensor data. *Remote Sens. Environ.* **2010**, *114*, 426–439. [CrossRef]
40. He, C.; Shi, P.; Xie, D.; Zhao, Y. Improving the normalized difference built-up index to map urban built-up areas using a semiautomatic segmentation approach. *Remote Sens. Lett.* **2010**, *1*, 213–221. [CrossRef]
41. Al-Bilbisi, H.; Tateishi, R. Using satellite remote sensing data to detect land use/cover changes and to monitor land degradation in central Jordan. *J. Jpn. Soc. Photogramm. Remote Sens.* **2003**, *42*, 4–18. [CrossRef]
42. Gandhi, G.M.; Parthiban, S.; Thummalu, N.; Christy, A. Ndvi: Vegetation Change Detection Using Remote Sensing and Gis—A Case Study of Vellore District. *Procedia Comput. Sci.* **2015**, *57*, 1199–1210. [CrossRef]
43. Jordan Ministry of Education. 2020. School in Jordan. Ministry of Education. Retrieved. 2020. Available online: http://www.e-daleel.gov.jo/. (accessed on 26 March 2021).
44. Jordan Ministry of Health. 2020. Health Centres. Retrieved. 2020. Available online: https://moh.gov.jo/AR/List/%D8%A7%D9%84%D9%85%D8%B1%D8%A7%D9%83%D8%B2_%D8%A7%D9%84%D8%B5%D8%AD%D9%8A%D8%A9. (accessed on 27 March 2021).
45. Cain, M.K.; Zhang, Z.; Yuan, K.-H. Univariate and multivariate skewness and kurtosis for measuring nonnormality: Prevalence, influence and estimation. *Behav. Res. Methods* **2017**, *49*, 1716–1735. [CrossRef] [PubMed]
46. Anbar, A.; Abu Sabha, K. Internal Migration in Jordan: Its Size, and Trends. *Jordan J. Soc. Sci.* **2009**, *2*, 211–255.
47. Alassaf, A.; Majdalwai, M.; Nawash, O. Factors affecting farmer's decision to continue farm activity in marginal areas of Jordan. *Afr. J. Agric. Res.* **2011**, *6*, 2755–2760.
48. Zreqat, D.; Alhusban, Y. Land Cover Changing Detection by GIS and Air Photographs: Bourma*, Sub-district of Jerash. *Jordan J. Soc. Sci.* **2012**, *5*, 1–14.
49. Al-Bilbisi, H. Spatial Monitoring of Urban Expansion Using Satellite Remote Sensing Images: A Case Study of Amman City, Jordan. *Sustainability* **2019**, *11*, 2260. [CrossRef]
50. Soffianian, A.; Ahmadiadoushan, M.; Yaghmael, L.; Falahatkar, S. Mapping and analyzing urban expansionusing remotely sensed imagery in Isfahan, Iran. *World Appl. Sci. J.* **2010**, *9*, 1370–1378.
51. Burby, R.J.; Deyle, R.E.; Godschalk, D.R.; Olshansky, R.B. Creating Hazard Resilient Communities through Land-Use Planning. *Nat. Hazards Rev.* **2000**, *1*, 99–106. [CrossRef]
52. Al-Habees, M. Spatial analysis of Health Centers in the Governorate of Amman, Jordan. *J. Med. J.* **2013**, *47*, 44–56. [CrossRef]
53. Jordan General Budget Department. 2022. List of Projects for the year 2022. Retrieved. 2022. Available online: http://gbd.gov.jo/Uploads/Files/gbd/law-min/2022/ar/4.pdf (accessed on 1 June 2022).
54. Bhatti, S.S.; Tripathi, N.K. Built-up area extraction using Landsat 8 OLI imagery. *GIScience Remote Sens.* **2014**, *51*, 445–467. [CrossRef]
55. Agung, I.N. Identical population estimates using the exponential and geometric growth functions. *Maj. Demogr. Indones* **1993**, *20*, 69–74.
56. Chander, G.; Markham, B.L.; Helder, D.L. Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. *Remote Sens. Environ.* **2009**, *113*, 893–903. [CrossRef]
57. Firl, G.; Carter, L. *Calculating Vegetation Indices from Landsat 5 TM and Landsat 7 ETM+ Data*; Colorado State University: Fort Collins, CO, USA, 2011.
58. Vogelmann, J.E.; Howard, S.M.; Yang, L.; Larson, C.R.; Wylie, B.K.; Van Driel, J.N. Completion of the 1990s National Land Cover Data set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources. *Photogramm. Eng. Remote Sens.* **2001**, *67*, 650–662.

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Types, Modes and Influencing Factors of Urban Shrinkage: Evidence from the Yellow River Basin, China

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Abstract: Following the appearance of urban shrinkage in Western countries, scholars have taken note of increasing amounts of urban shrinkage with significant regional characteristics in China in recent years. Focusing on the Yellow River Basin, this study comprehensively measured prefecture-level and county-level city shrinkage based on China's fifth, sixth and seventh national census data. Furthermore, the spatiotemporal patterns, types and modes of urban shrinkage were analyzed, and the factors influencing urban shrinkage were explored using a multiple linear regression model and a sorting model. The study results show that the number of shrinking cities and the shrinking degree significantly increased at the prefecture and county levels in the last 20 years. The identified shrinking cities are concentrated in the upper and middle reaches of the river basin, spatially configured around major cities and along the high-speed railway line. The regional pattern shows a typical "core–periphery" characteristic. Peripheral shrinkage is the main mode in which cities shrink. The strength and speed of economic development and industrial transformation positively affect urban shrinkage; the ageing degree, high-speed railway opening and other factors negatively affect urban shrinkage.

Keywords: urban shrinkage; spatiotemporal pattern; shrinkage type; shrinkage mode; influencing factor; the Yellow River Basin

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1. Introduction

In the mid-20th century, urban shrinkage characterized by massive population loss appeared successively in developed industrial countries, such as the United Kingdom and Germany [1,2]. These countries were global leaders of urbanization during the first and second industrial revolutions and first experienced severe population loss during the deindustrialization process in the 20th century, co-occurring with the emergence of a series of social problems [3,4]. In the 1980s, the German scholar Häußermann formally proposed the term "shrinking cities" to describe the phenomenon of population loss and economic decline in the Ruhr region of Germany as a result of deindustrialization and suburbanization [5]. Since then, urban shrinkage has received widespread scholarly attention, with new theoretical and empirical studies continually emerging to discuss the phenomenon in Western Europe, the United States, Japan and other developed countries. In the 21st century, scholars began to focus on urban shrinkage in developing countries, with significant results in China, Russia, etc. [6,7]. In an empirical study of urban shrinkage across the globe from 2000 to 2019, China was ranked first in terms of the number of shrinking cities, accounting for 13.6% of the shrinking cities worldwide [8]. Many studies have shown that deindustrialization has also affected China, with urban shrinkage concentrated in resource-based cities and old industrial bases [9]. Moreover, a growing body of research suggests that China's shrinking cities include more than just these areas [10]. Even in China, which is still in a phase of rapid urbanization, it is no longer realistic to adhere to traditional forms of urban development and planning.

The loss of the urban population presents diverse shrinkage modes. Western scholars have divided shrinkage modes into two main categories based on the spatial distribution of depopulation. The first category is perforated shrinkage, represented by European industrial cities [11], as in the 1930s Manchester [2] and 1960s Liverpool and Leipzig [12]. Over time, these cities lost residents in several inner-city areas, resulting in a staggered distribution of growth plots and shrinkage plots within the city. The second category is doughnut shrinkage, represented by the Rust Belt in the northeastern United States [13], as exemplified by Detroit in the 1950s [14], where there was a massive population loss in the whole inner city. In addition, a few areas show anti-doughnut shrinkage, which describes the phenomenon of peripheral suburbs shrinking annularly and core areas growing, such as in the Paris region of France in the second half of the 20th century [15]. These typical shrinkage modes have prominent characteristics and appeared early, which provided comparative samples for the later study of urban shrinkage modes in different countries and regions. For example, in the 1990s, Izmir's shrinkage was characterized by a doughnut shape [16] and in the 2000s Chiba prefecture in Tokyo experienced a mode of shrinkage defined as urban perforation [17]. Moreover, some shrinking cities in China show a phenomenon similar to the anti-doughnut mode [18].

Concerning the factors influencing urban shrinkage, many studies have focused on developed countries and have shown that demographic change, deindustrialization, suburbanization and globalization are the dominant factors of urban shrinkage [19,20]. For example, the problems of childlessness and population ageing are the leading causes of urban shrinkage in Japan. Deindustrialization and emigration are significant drivers of urban shrinkage in Germany. In the US, urban shrinkage is a regional phenomenon mainly found in the Rust Belt and metropolitan areas, accompanying deindustrialization and suburbanization as the primary causes of shrinkage. In addition, with globalization, the restructuring of global production relations has led to a crisis of urban shrinkage in industrial countries, as seen in Europe and the United States [21]. Unlike developed countries, China's urban shrinkage resembles a microcosm of the uneven development between cities. Since the era of reform and opening up, China has experienced rapid industrialization and massive urban expansion, with significant trends identified as "migration to the cities" and the "flight of peacocks to the southeast" [22]. The growth of some cities has also led to shrinkage in the affected regions. This means that urban shrinkage in China cannot be attributed to the same causes as that in developed countries but must be comprehensively considered by synthesizing the characteristic factors of China's urban development.

In 2019, the ecological conservation and high-quality development of the Yellow River Basin became part of the national strategy, and the urban growth and shrinkage of that area has attracted more scholarly attention. Studies have shown that urban shrinkage has existed for some time in the Yellow River Basin [23,24] and have greatly enhanced the understanding of urban shrinkage in the region. However, these studies are mostly scaled to the prefecture level. County cities, as the basic component of China's urban system, also present the shrinkage phenomenon and need more attention. In addition, the types and modes of urban shrinkage have not been explored in depth. According to life cycle theory [25], there exists a classification of shrinkage patterns and a division of shrinkage degrees and shrinkage trajectories in urban shrinkage processes. Based on these results, from prefecture-level and county-level perspectives, using the periods 2000–2010 and 2010–2020, this work explores three questions: (1) What are the time-series changes in the proportion and degree of urban shrinkage in the Yellow River Basin? What degrees and trajectories of urban shrinkage can be observed?; (2) With recognition of the urban shrinking pattern at the prefecture and county levels, are there typical spatial structures and shrinkage modes in the Yellow River Basin?; (3) What factors influence the degree and mode of urban shrinkage in the Yellow River Basin? What are the similarities and differences in the drivers of urban shrinkage in the Yellow River Basin compared to those of Western developed countries with an earlier history of shrinkage? The study aims to provide empirical support for government and urban planners to promote the regrowth and

high-quality development of shrinking cities in the Yellow River Basin and to contribute a typical case in China to the study of urban shrinkage globally.

2. Materials and Methods

2.1. Study Area

On the one hand, the Yellow River Basin spans three economic zones and the three natural regions of eastern, central and western China. The complex socioeconomic factors and natural conditions increase the diversity of urban shrinkage. On the other hand, many cities along the basin have developed over a long period and are in different urban development stages, which provides an opportunity to explore urban shrinkage in the context of urban development in China. This work draws upon the administrative division system of 2020 and defines 115 prefecture-level administrative units and 936 county-level administrative units in the Yellow River Basin as study units (Figure 1). To effectively measure urban shrinkage, the urban data of three time points are unified against the standard set by 2020 zoning. For prefecture-level cities without municipal districts under their jurisdiction (such as Alashan League and Manzhouli City), the area where the city administrative unit is located is counted as the municipal district. In contrast, county-level cities geographically within prefecture-level cities are unified as municipal counties.

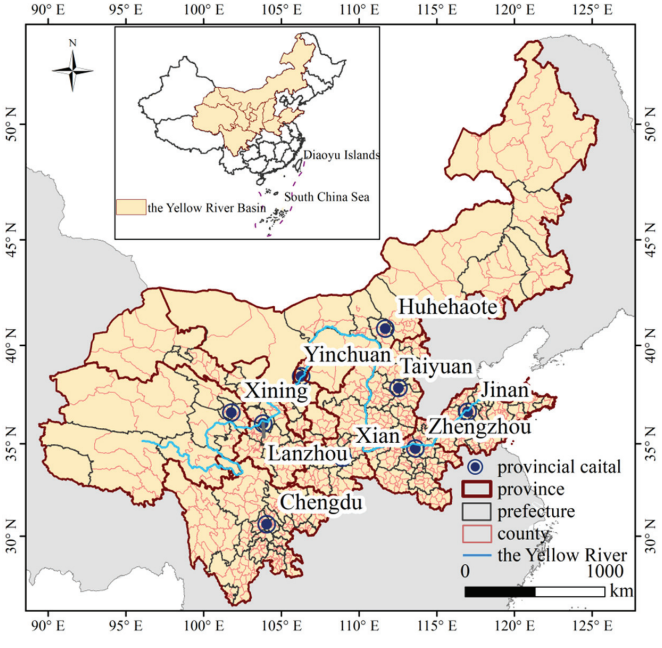


Figure 1. Study area: the Yellow River Basin.

2.2. Research Methods

2.2.1. Concept Definition and Measurement of Urban Shrinkage

At present, there is no unified definition of urban shrinkage. In this study, urban shrinkage is understood as a process of population reduction caused by various regional driving factors, showing different types and modes. Considering that population decline has been widely recognized as a key indicator for identifying and measuring urban shrinkage [26–28], based on census data registered by the National Bureau of Statistics of China every ten years, urban shrinkage is defined as the process in which the population change rate of a city is negative between two census years (i.e., 2000–2010 and 2010–2020). The word "shrinking cities" is a common expression used to describe places displaying signs

of urban shrinkage. The urban shrinkage model has been widely used to measure urban shrinkage [29]. The calculation is shown in Equations (1) and (2).

$$Shrinking1 = \Delta pop1 = (pop2010 - pop2000)/pop2000 * 100\% \quad (1)$$

$$Shrinking2 = \Delta pop2 = (pop2020 - pop2010)/pop2010 * 100\%, \quad (2)$$

where pop_{2000}, pop_{2010}, and pop_{2020} represent the population of the corresponding year. *Shrinking*1 and *Shrinking*2 represent the urban shrinkage rates in 2000–2010 and 2010–2020, respectively; when the urban shrinkage rate is negative, the urban area has shrunk in the corresponding period. The smaller the urban shrinkage rate, the greater the shrinkage degree of the city.

2.2.2. Multiple Linear Regression Model

The multiple linear regression model is a method for the quantitative analysis of influencing factors and is used to explore the effect of explanatory variables on explained variables. This study applies the multiple linear regression model to explore the influence of different factors on the urban shrinkage in the Yellow River Basin from 2000 to 2020 and tests the stability of the spatial measurement results. The model constructed is as follows:

$$Shrinking3 = \alpha_0 + \sum_{i=1}^{n} \beta x_{it} + \varepsilon_{it}, \quad (3)$$

where *Shrinking*3 is the explained variable and x_{it} is the explanatory variable. i = 1..., N, indicating region i; t = 2000, 2010 or 2020, indicating the time.

2.2.3. Sorting Model

The sorting model is adapted to discrete data with natural ranking and can measure the influence of explanatory variables on ordinal variables. In the sorting model, the coefficients of the explanatory variables do not have a precise quantitative meaning, but their symbol and significance can still be used to judge the influence direction of the variables. When there are specific categories of shrinking cities in the Yellow River Basin, the sorting model can be applied to explore the influence direction of different factors on these categories. The model constructed is as follows:

$$Shrinking4 = \alpha_0 + \sum_{i=1}^{n} \beta x_{it} + \varepsilon_{it} \quad (4)$$

$$\begin{aligned} Shringking4 \quad &= 0(y* \le r_0), or \\ &= 1(r_0 < y* \le r_1), or \\ &= 2(r_1 < y* \le r_2), or \\ &\cdots\cdots \\ &= J(r_{J-1} < y* \le r_J) \end{aligned} \quad (5)$$

where $r_0 < r_1 < ... < r_J$ are the parameters to be estimated, which are called cut points. *Shrinking*4 is the explained variable; *Shrinking*4 = 0, 1, 2...; x_{it} is the explanatory variable. i = 1..., N, indicating region i; t = 2000, 2010 or 2020, indicating the period.

2.3. Indicator System and Data Sources

2.3.1. Selection of Influencing Factors of Urban Shrinkage

This study focuses on the main drivers of urban shrinkage in developed countries and the characteristic factors of urban shrinkage in China. Considering the natural and socioeconomic conditions of the Yellow River Basin, relevant studies [30–32], the data quality and availability, nine indicators are selected to construct a system affecting urban shrinkage in the Yellow River Basin, as shown in Table 1.

Table 1. Indicator system construction.

Variable	Variable Description
Economic development strength (GDP)	Gross National Product of base period
Economic development speed (GDP_G)	Gross National Product growth rate
Ageing degree (Ageing)	The change rate of ageing rate
Industrial structure transformation (Indust)	The change rate of the ratio of tertiary industry GDP to secondary industry GDP
High-speed railway opening (HSM)	A binary variable taking the value 1 if the city is severed by a high-speed railway and 0 in other cases
High-speed railway opening_economic development (HSM*GDP_G)	The interaction variable between the variable high-speed railway opening and the variable economic development speed
Urban air environment ($PM_{2.5}$)	The average value of Z value change rate of all units in $PM_{2.5}$ raster data
Urban natural environment (Slope)	The average value of Z value change rate of all units in DEM raster data.
Facility construction level (Invest)	The change rate of investment in fixed assets

Note: * indicates the product of two variables.

2.3.2. Data Sources

The population data come from China's fifth, sixth and seventh population censuses. The socioeconomic data come from the China Urban Statistical Yearbook, statistical yearbooks and statistical bulletins relating to the prefectures and counties in the Yellow River Basin. High-speed railway data come from the OpenStreetMap website (https://www.openstreetmap.org (accessed on 17 May 2021)) and the announcement of the China National Railway Administration. The slope data are calculated based on the DEM raster data provided by the Geospatial Data Cloud website (https://www.gscloud.cn/#page2 (accessed on 25 June 2021)). The $PM_{2.5}$ data come from the $PM_{2.5}$ remote sensing dataset provided by the Atmospheric Composition Analysis Group of Washington University in St. Louis. (https://sites.wustl.edu/acag/datasets/surface-pm2-5/#V4.CH.03 (accessed on 20 October 2021)). The nighttime light data are from the first 2000–2020 global 500 m resolution NPP-VIIRS-like nighttime light dataset produced by a deep learning model [33].

3. Results

3.1. Temporal Evolution and Types of Urban Shrinkage in the Yellow River Basin

From 2000 to 2020, the number of shrinking cities showed a significant increase in the Yellow River Basin (Table 2). At the prefecture level, 34 cities and 57 cities experienced urban shrinkage in 2000–2010 and 2010–2020, accounting for 29.57% and 49.57% of all prefecture-level cities, respectively. The proportion of shrinking cities was higher at the county level than at the prefecture level, accounting for 38.46% and 65.28% of all county-level cities in 2000–2010 and 2010–2020, respectively. There were 52 shrinking municipal districts and 308 shrinking municipal counties between 2000 and 2010, accounting for 18.98% of municipal districts and 46.53% of municipal counties, respectively; between 2010 and 2020, the number of shrinking cities increased dramatically, at 108 municipal districts and 503 municipal counties, accounting for 39.42% of municipal districts and 75.98% of municipal counties. Above all, the shrinkage ratio of municipal counties is significantly higher than that of municipal districts, implying that a large population tends to leave the urban periphery (municipal counties) and gather in the urban center (municipal districts). In addition, many municipal districts have shrunk, reflecting that some people migrate from the urban centers to regional core cities with greater economic strength.

Table 2. Statistics of shrinking cities at the prefecture and county levels.

Level	Unit	Statistic	2000–2010			2010–2020		
			Shrinkage	Non-Shrinkage	Total	Shrinkage	Non-Shrinkage	Total
Prefecture	City	Number	34	81	115	57	58	115
		Rate	29.57%	70.43%	100%	49.57%	50.43%	100%
County	Municipal county	Number	308	354	662	503	159	662
		Rate	46.53%	53.47%	100%	75.98%	24.02%	100%
	Municipal district	Number	52	222	274	108	166	274
		Rate	18.98%	81.02%	100%	39.42%	60.58%	100%
	Total	Number	360	576	936	611	325	936
		Rate	38.46%	61.54%	100%	65.28%	34.72%	100%

To objectively understand the process of urban shrinkage, this study further classifies shrinking types according to the shrinking degree and shrinking trajectory of shrinking cities in 2000–2010 and 2010–2020. Based on the urban shrinkage rate, the work uses ArcGIS's natural breaking points method to classify the degree of shrinking cities into two types: slight shrinkage and severe shrinkage. To ensure comparability, the degree classification is standardized uniformly according to statistics from 2010–2020. Because prefecture-level and county-level cities have different shrinking degrees, they have different division standards. Based on the length of urban shrinkage, the trajectories of shrinking cities are classified into four types: worsening shrinkage, slowing shrinkage, steady shrinkage and recent shrinkage. The specific classification criteria are shown in Table 3.

Table 3. Criteria for the classification of shrinking city types.

Classification of Shrinking Degree	Division Standard	Classification of Shrinking Trajectory	Division Standard
Slight shrinkage	[−0.1020,0) (prefecture level)	Worsening shrinkage	*Shrinking*2 < *Shrinking*1 < 0
	[−0.2040,−0.1020) (county level)	Slowing shrinkage	*Shrinking*1 < *Shrinking*2 < 0
Severe shrinkage	[−0.2997,0) (prefecture level)	Recent shrinkage	*Shrinking*2 < 0 < *Shrinking*1
	[−0.5994,−0.2997) (county level)	Steady shrinkage	*Shrinking*1 < 0 < *Shrinking*2

Note: *Shrinking*1 refers to urban shrinkage in 2000–2010; *Shrinking*2 refers to urban shrinkage in 2010–2020.

The classification results of the urban shrinking degree in 2000–2010 and 2010–2010 are shown in Table 4. Between 2000 and 2010, slight shrinkage was the dominant type, accounting for 79.41% of all prefecture-level shrinking cities (27 out of 34) and 98.33% of all county-level shrinking cities (354 out of 360); severe shrinkage was less common, accounting for 20.59% of all prefecture-level shrinking cities (seven out of 34) and 1.67% of all county-level shrinking cities (six out of 360). Between 2010 and 2020, the proportion of cities with slight shrinkage decreased slightly, reaching 70.18% of all prefecture-level shrinking cities (40 out of 57) and 94.93% of all county-level shrinking cities (580 out of 611); meanwhile, the proportion of cities with severe shrinkage increased to 29.82% (17 out of 57) and 5.07% (31 out of 611) at the prefecture and county levels, respectively. Above all, most shrinking cities experienced slight shrinkage in the Yellow River Basin in 2000–2010 and 2010–2020, but the number and proportion of severely shrinking cities showed an upwards trend.

Table 4. Statistics on the classification of shrinking degrees of prefecture-level and county-level shrinking cities.

Level	Statistic	2000–2010			2000–2010		
		Slight Shrinkage	Severe Shrinkage	Total	Slight Shrinkage	Severe Shrinkage	Total
Prefecture	Number	27	7	34	40	17	57
	Rate	79.41%	20.52%	100%	70.18%	29.82%	100%
County	Number	354	6	360	580	31	611
	Rate	98.33%	1.67%	100%	94.93%	5.07%	100%

Cities in the Yellow River Basin are classified by their type of shrinking trajectory, as shown in Table 5, with 64 prefecture-level cities and 676 county-level cities following the predicted trajectory; i.e., these cities have a negative urban shrinkage rate in one or both study periods. Most cities present recent shrinkage among the prefecture and county levels, reaching 46.88% (30 out of 64) and 46.75% (316 out of 676), respectively; cities with worsening shrinkage represent the second-highest proportion, reaching 28.13% (18 out of 64) and 27.66% (187 out of 676); next are the cities with slowing shrinkage, with 14.06% (9 out of 64) and 15.98% (108 out of 676); and the cities with steady shrinkage are the lowest in number, accounting for 10.93% (7 out of 64) and 9.61% (65 out of 676). Furthermore, comparing the number of cities with steady shrinkage with the number of cities with worsening shrinkage and slowing shrinkage, nearly 1/5 of the shrinking cities in 2000–2010 evolved into non-shrinking cities in 2010–2020, while nearly 4/5 of them continued to shrink. Most shrinking cities in the Yellow River Basin show a continuous population decline. Moreover, there are more cities where the shrinking is worsening rather than slowing, demonstrating an increase in the shrinking degree of most shrinking cities. In addition, the large proportion of cities with recent shrinkage indicates that many cities began to shrink in 2010–2020, newly facing the challenge of continuous population decline.

Table 5. Statistics on the classification of shrinking trajectories of prefecture-level and county-level shrinking cities.

Level	Statistic	Worsening Shrinkage	Slowing Shrinkage	Recent Shrinkage	Steady Shrinkage	Total
Prefecture	Number	18	9	30	7	64
	Rate	28.13%	14.06%	46.88%	10.93%	100%
County	Number	187	108	316	65	676
	Rate	27.66%	15.98%	46.75%	9.61%	100%

3.2. Spatial Patterns and Modes of Urban Shrinkage in the Yellow River Basin

The spatial pattern of urban shrinkage in the Yellow River Basin is shown in Figure 2. At the prefecture level, shrinking cities are mainly concentrated in the upper and middle reaches of the Yellow River Basin. In addition, shrinking cities tend to present as block and circular agglomerations around main cities and core areas. For example, Wuwei, Zhangye, Haidong, Guyuan and other shrinking cities formed two semicircular shrinking areas surrounding the larger cities of Xining and Lanzhou in 2000–2010. In some zones along the high-speed rail line, there is a striped distribution of shrinking cities. For example, Tianshui, Dingxi, Baoji and other cities along the Lanxi high-speed railway shrank to form a continuous striped layout in 2010–2020; these cities were mainly located at interprovincial junctions. At the county level, between 2000 and 2010, the shrinking districts (counties) showed block and patchy cluster distributions mainly concentrated in the marginal areas of many provinces in the upper reaches. For example, the northeast of Qinghai Province and the northwest of Gansu Province were areas with a concentrated distribution of shrinking cities. Between 2010 and 2020, shrinking cities showed an extensive continuous distribution

and were generally distributed in the peripheral regions of the Yellow River Basin. The proportion of shrinking cities in the middle and lower reaches increased significantly.

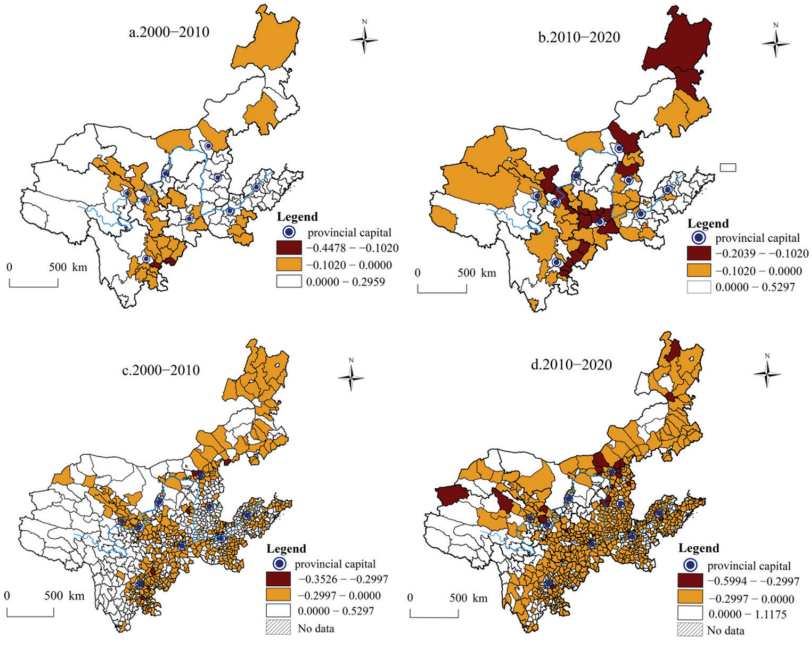


Figure 2. Spatial characteristics of urban shrinkage.

Above all, the shrinking cities' spatial distribution and aggregation characteristics show a typical "core-periphery" characteristic in multiscale administrative divisions in the Yellow River Basin. At the prefecture level and above, the surrounding areas of the main cities and core areas in urban agglomerations and metropolitan areas tend to shrink significantly, while the main cities and core areas maintain stable growth. For example, the nine provincial capitals achieved population growth, and the growth rates were more than 10% in 2000–2010 and 2010–2020, while the population of their surrounding cities generally decreased. At the county level, municipal districts are still the preferred locations for population agglomeration, while municipal counties, with relatively undeveloped economies, are less attractive and are widely facing population decline. Considering this spatial characteristic, this study classifies the modes of prefecture-level shrinking cities according to the relationship between the shrinking states of municipal districts and counties. Considering that the municipal district is where a city's economic activities are concentrated, shrinkage here is regarded as the shrinkage of the urban center, and the shrinkage of the municipal county is regarded as the shrinkage of the urban periphery. Finally, shrinking cities are classified into three modes: global shrinkage, meaning the shrinkage rate of the urban center (municipal district) and the urban periphery (municipal county) is negative; central shrinkage, meaning the shrinkage rate of the urban center is negative and the urban periphery is positive; and peripheral shrinkage, meaning the shrinkage rate of the urban center is positive and the urban periphery is negative. In addition, considering that some growing prefecture-level cities still have individual county-level units that are shrinking, this study designates a fourth shrinkage mode: local shrinkage, meaning the shrinkage rate of the whole city (prefecture-level city) is positive and local areas (individual county-level units) in the city are negative. It should be noted that local shrinking cities still show an increasing total population; however, a few county-level units in these cities experience a decrease in population, presenting an embedded structure of prefecture-level city growth and county-level unit shrinkage. Representative maps of the four modes are shown in Figure 3.

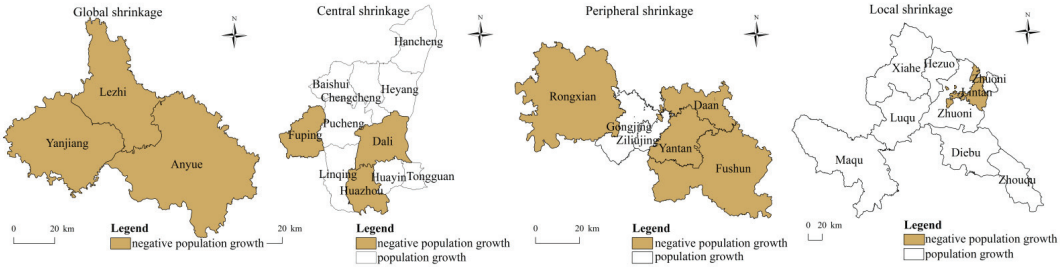


Figure 3. Four modes of urban shrinkage.

Figure 4 shows the distribution of the various modes of shrinking cities in the Yellow River Basin. There were 93 and 109 prefecture-level cities with global, central, peripheral or local shrinkage in 2000–2010 and 2010–2020, respectively. Between 2000–2010 and 2010–2020, the number of global shrinking cities increased from 10 to 19, and their proportion increased from 10.75% (10 of 93) to 17.43% (19 of 109). These cities are relatively scattered and mainly distributed in the upper and middle reaches of the river basin. Central shrinkage appeared only in 2000–2010 and occurred in only two cities, Weinan and Bazhong; it is worth noting that the two cities experienced global shrinkage in 2010–2020. Between 2000–2010 and 2010–2020, the number of peripheral shrinking cities increased from 17 to 38, and their proportion increased from 23.66% (17 of 93) to 34.86% (38 of 109). Above all, peripheral shrinkage is the primary shrinkage mode of shrinking cities in the Yellow River Basin. Peripheral shrinking cities are widely distributed across the region and show a block and circular agglomeration distribution. For example, from 2010 to 2020, Xinzhou, Lvliang and other cities formed a circular zone of depopulation around Taiyuan and Jinzhong, which confirms that the central cities have a strong attraction to the population in the periphery of the surrounding cities in the Yellow River Basin. In addition, the number and proportion of local shrinking cities decreased, with the number falling from 59 to 52 and the proportion decreasing from 63.44% (59 of 93) to 47.7% (52 of 109). Specifically, among the 59 local shrinking cities in 2000–2010, nearly three out of five of the cities still experienced local shrinkage in 2010–2020, nearly 2/5 of the cities evolved into peripheral shrinking cities or global shrinking cities in 2010–2020, and only one city achieved full growth in each of its county units in 2010–2020. Cities with local shrinkage may appear to be growing overall but may turn into shrinking cities over time. Cities with local shrinkage are widely distributed in the Yellow River Basin. In addition, the individual county-level units of some regional core cities, for example, Zhongmou and Gongyi in Zhengzhou City in 2010–2020, exhibit shrinkage mainly in the urban fringe. Due to the polarizing effect of cities experiencing growth, the population may cluster in the urban center, forming a spatial pattern of overall urban growth and local shrinkage.

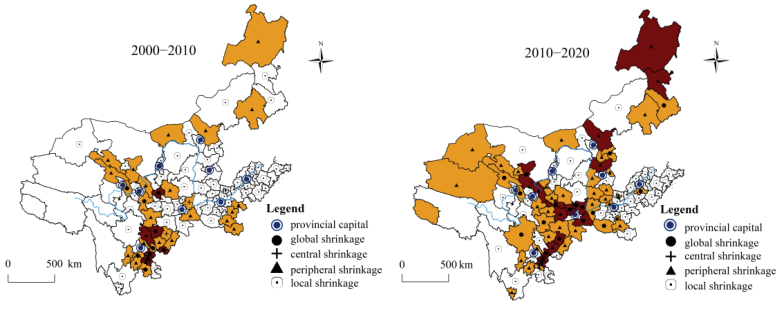


Figure 4. Spatial distribution of shrinking cities with different shrinkage modes.

3.3. Factors Influencing Urban Shrinkage in the Yellow River Basin

The multiple linear regression model and sorting model were used to analyze the influencing factors of urban shrinkage in the Yellow River Basin. The first model takes the urban shrinkage rate as the explained variable, reflecting the effect of influencing factors on the urban shrinking degree. The second model indicates the direction of influence of factors on the urban shrinkage mode as the explained variable. In model 2, the four modes of global shrinkage, central shrinkage, peripheral shrinkage and local shrinkage are assigned ranks of 1, 2, 3, and 4, respectively. In other words, the shrinking degree of cities is ranked from deep to shallow within the four modes, from the global shrinking city to the central shrinking city to the peripheral shrinking city to the local shrinking city. In addition, growing cities with a positive urban shrinkage rate in each county-level unit are assigned a rank of 5 in comparison with the four shrinking modes in the sorting model. The multiple linear regression model results are shown in Model 1 of Table 6. The sorting model adopts the ordered logit model (model 2(a)) and the ordered probit model (model 2(b)) for regression calculation. Following the comparison of the pseudo r^2 values of model 2(a) and model 2(b) (the larger the pseudo r^2 value, the better the explanatory variable explains the explained variable), the measurement results of "2000–2010" in model 2(b) and "2010–2020" in model 2(a) are used to analyze the influencing factors of the shrinkage mode. The results are analyzed as follows.

Table 6. Results of model regression calculation.

	Model 1		**Model 2**			
			(a)		**(b)**	
Variables	**2000–2010**	**2010–2020**	**2000–2010**	**2010–2020**	**2000–2010**	**2010–2020**
GDP	0.1163 * (1.75)	0.1628 ** (2.49)	0.8520 (0.66)	3.067 ** (2.11)	0.4334 (0.66)	1.567 * (1.95)
GDP_G	0.0067 (1.64)	0.0379 * (1.78)	0.0073 (0.08)	0.8115 ** (1.78)	−0.0083 (0.08)	0.5791 ** (2.28)
Ageing	−0.1990 *** (−4.14)	−0.1410 *** (−4.21)	−5.286 *** (−4.78)	−3.719 *** (−3.79)	−3.013 *** (−4.78)	−1.648 *** (−3.90)
Indust	0.0691 ** (2.48)	0.0021 (0.18)	0.6616 (1.18)	−0.2136 (−0.79)	0.3080 (1.18)	−0.0563 (−0.40)
HSM	−0.1132 *** (−2.71)	−0.15030 ** (−2.44)	−2.153 ** (−2.55)	0.2392 (0.19)	−1.404 *** (−2.55)	0.1563 (0.21)
HSM*GDP_G	0.0258 *** (3.17)	0.1885 *** (3.81)	0.3892 ** (2.22)	−0.8996 (−0.84)	0.2686 *** (2.22)	−0.4868 (−0.79)
$PM_{2.5}$	−0.2728 *** (−4.61)	0.0049 * (1.95)	−3.488 *** (−2.81)	0.0856 (1.61)	−2.008 *** (−2.81)	0.0631 ** (2.10)
Slope	0.0045 (1.48)	−0.0083 ** (−2.48)	0.0292 (0.50)	−0.2113 *** (−3.00)	0.0092 (0.50)	−0.1305 *** (−3.26)
Invest	−0.0001 (−0.08)	−0.0068 * (−1.95)	0.0066 (0.42)	−0.0688 (−1.02)	0.0030 (0.42)	−0.0372 (−0.90)
Number of observations	115	115	115	115	115	115
Average VIF	2.02	2.62	2.02	2.62	2.02	2.62
R^2/Pseudo R^2	0.4513	0.5040	0.1751	0.1656	0.1799	0.1463

Note: ***, **, * respectively indicate that they have passed the significance test of 1%, 5% and 10%. The values in the table represent the coefficient value of the variable in the regression, and the values in () represent the Z value of the regression result.

3.3.1. The Role of Various Influencing Factors in Urban Shrinkage

First, the study ranks the effect of the influencing factors in Model 1 and classifies the direction of the influence in Model 2. In Model 1, GDP, GDP_G, Ageing, Indust, HSM, HSM*GDP_G, Invest, $PM_{2.5}$ and Slope pass the significance test, indicating that these factors affect the urban shrinkage rate; that is, they act on the urban population agglomeration and dispersion. The effects of the influencing factors are ranked according to the absolute value of the variable regression coefficient (| coef |) in 2000–2010 and 2010–2020. In 2000–2010, the order of effect is $PM_{2.5}$ > Ageing > GDP > HSM > Indust > HSM*GDP_G. In 2010–2020, the order of effect is HSM*GDP_G > GDP > HSM > Ageing > GDP_G > Slope > Invest >

$PM_{2.5}$. In Model 2, GDP, GDP_G, Ageing, HSM, HSM*GDP_G, $PM_{2.5}$ and Slope pass the significance test, indicating that these factors affect the urban shrinkage mode. Among them, GDP, GDP_G and HSM*GDP_G positively affect the urban shrinkage mode, while Ageing, HSM, $PM_{2.5}$ and Slope negatively affect the urban shrinkage mode.

3.3.2. Economic Development Strength and Speed and Urban Shrinkage

In Model 1, GDP passes the 10% and 5% significance tests, and the regression coefficients increase from 0.1163 to 0.1628 in the two study periods; GDP_G does not pass the significance test in 2000–2010 but passes the 10% significance test in 2010–2020 with a coefficient of 0.0379. This result indicates that the strength and speed of economic development play an increasingly positive role in population dispersion. Cities with weak economies and slow economic development tend to experience population outflows, leading to urban shrinkage. In Model 2, GDP and GDP_G pass the 5% significance tests in 2010–2020, and the regression coefficients are positive (3.067 and 0.8115). This indicates that cities with low economic development strength and speed are also more likely to experience global shrinkage. This finding can explain the existence of shrinking zones around provincial capitals and core cities at the prefecture level and the mode of peripheral shrinkage. Theoretically, economically developed areas tend to have a powerful pull on the surrounding population. However, their limited economic power is not yet sufficient to produce a spill-over effect on their surrounding areas, leading to significant shrinkage of the surrounding cities.

3.3.3. Demographic Ageing Level and Urban Shrinkage

In Model 1 and Model 2, Ageing passes the 1% significance test with negative coefficients (−0.1990, −0.1410, −3.013, −3.719), and Ageing is at the forefront of the ranking of each variable by their coefficient in Model 1. Clearly, this factor, playing a vital role in urban shrinkage in Western countries, also affects city shrinkage in the Yellow River Basin. On the one hand, China's long-standing one-child policy has resulted in a low birth rate for a long time, contributing to the rapid growth of the ageing rate and adding to the local economic burden. This is not conducive to a city's development and contributes to the progress of urban shrinkage. On the other hand, a large ageing population means a shortage of young laborers, resulting in a lack of sufficient labor to support urban construction and blocking the improvement of urban economic vitality. This, in turn, weakens a city's attractiveness to young people and aggravates the loss of the young population. These factors can accelerate urban shrinkage and increase the probability of global shrinkage.

3.3.4. Industrial Structure Transformation and Urban Shrinkage

In Model 1, Indust passes the 5% significance test, and the regression coefficient is positive (0.0691) in 2000–2010, indicating that industrial structure transformation has a positive effect on urban shrinkage. Upgrading the industrial structure can stimulate the economic vitality of cities and drive population inflows to effectively curb urban shrinkage. However, there is no significant correlation between urban shrinkage and Indust in 2010–2020, indicating that the industrial structure transformation does not have a sustained effect on urban population clustering in the Yellow River Basin. This can be understood in two ways. First, the degree of industrial structure transformation is slow, and the secondary industry is still the pillar industry in most cities. In the Yellow River Basin, the output value of the secondary industry in shrinking cities and industrial cities accounts for 39.55% and 43.22% of GDP, respectively. In contrast, in the UK and Germany—the countries that had an early industrial start—the secondary industry's output value accounted for only 33.7% and 25.4% of GDP, respectively, as early as 2000. Second, combined with the theory of path dependency, many cities underwent a deindustrialization process to a high degree but with low quality due to technical constraints [34]. This incomplete deindustrialization has limited the sustainable role of industrial structure transformation in mitigating urban shrinkage. In Model 2, Indust fails to pass the significance test in both periods; that is, the industrial structure transformation has no impact on the urban shrinkage mode. Industrial

development in urban areas brings more employment opportunities, and the population in all parts of the cities can find employment.

3.3.5. High-Speed Rail Opening and Urban Shrinkage

In Model 1, HSM passes the significance test at 1% and 5% in the two time periods, with negative coefficients of −0.1132 and −0.1503, respectively, showing that the high-speed rail opening in shrinking cities increases population outflow and intensifies urban shrinkage; this finding has been addressed in related studies [35]. HSM*GDP_G is introduced to further analyze the impact of high-speed rail on population agglomeration in cities with different levels of economic development. The results show that HSM*GDP_G passes the 1% significance test in both study periods, with regression coefficients of 0.0258 and 0.1885, respectively. This indicates that in cities with strong economies, high-speed rail opening pulls the population into the city and reduces the possibility of urban shrinkage. Conversely, in cities with economic disadvantages, high-speed rail opening accelerates the loss of urban population and further leads to urban shrinkage. This finding explains the spatial characteristics of the striped distribution of shrinking cities along the high-speed railway line in the Yellow River Basin. Cities with better economic development do not form a continuous striped layout. In Model 2, HSM passes the 1% significance test with a negative coefficient (−1.404), and HSM*GDP_G passes the 1% significance test with a positive coefficient (0.2686) in 2000–2010. This result indicates that high-speed rail opening increases the probability of cities experiencing global shrinkage. High-speed rail opening provides a convenient channel for urban young people and high-quality talent to work elsewhere, resulting in urban center decline due to the lack of labor force to construct the city and causing the emergence of central and even global shrinkage. In addition, HSM*GDP_G does not pass the significance test in 2010–2020, which can be explained by the fact that the improvement in high-speed railway facilities provided more equitable transport services for different groups of people within the city and enabled the population in the urban center and periphery to enjoy the same opportunities to migrate to other cities.

3.3.6. Urban Environment, Facility Construction Level and Urban Shrinkage

In Model 1 and Model 2, $PM_{2.5}$ passes the 1% significance tests in 2000–2010, and the coefficients are negative (−0.2728, −2.008), indicating that the urban air environment had a negative effect on the degree and mode of urban shrinkage in 2000–2010. The deterioration of the urban air environment drives the population out to search for a better living environment. Especially in the urban center, where there are heavy haze conditions due to the long-term convergence of economic activities, residents choose to move out, forming central shrinkage and further leading to the phenomenon of global shrinkage. $PM_{2.5}$ passes the 10% significance tests for 2010–2020 in Model 1, and the coefficients are positive (0.0049); however, the variable fails to pass the significance tests in Model 2. Although this shift in influencing direction and significance is contrary to the perception that deteriorating urban air environments reduce attractiveness to the population, it is understandable that higher urban $PM_{2.5}$ values represent, to some extent, the existence of more intensive economic activities. Therefore, driven by economic interests, the population is more highly attracted to cities with high $PM_{2.5}$ values, which reduces the urban shrinkage degree. In addition, the general improvement in the urban environment weakens the negative effect of urban air environmental problems on population growth. In particular, the environmental problems in urban centers receive more attention and treatment, which can effectively attract the urban population to stay in the center and reduce urban shrinkage and especially global shrinkage. In addition, the regression coefficient of $PM_{2.5}$ drops in the ranking from first to last in the two time periods in Model 1, which is further proof that the influence of urban air conditions on population concentration is weakened. In Models 1 and 2, Slope does not pass the significance test in 2000–2010, but it passes the 5% and 1% significance tests with negative coefficients (−0.0083 and −0.2113) in 2010–2020, indicating that the negative effect of urban slope on the degree and mode of urban shrinkage is beginning to emerge.

With the continuous expansion of the urban scale and the decrease in exploitable land, slope's restrictive effect on urban land development becomes more pronounced, limiting the further concentration of the population and causing urban shrinkage. Notably, driven by urban growth, some shrinking cities experience contradictory development between population shrinkage and land expansion due to the continued development of urban land [36]. This can further aggravate urban shrinkage (especially urban central shrinkage), causing, for example, increases in unused infrastructure and abandoned urban greenery. In Model 1, Invest passes the 10% significance test for 2010–2020 with a negative coefficient (−0.0068), again suggesting that continued investment in infrastructure to maintain the appearance of urban growth in shrinking cities cannot effectively retain population.

4. Discussion

4.1. Validation and Supplementation of Urban Shrinkage Measures Based on Nighttime Lighting Data

The article identifies shrinking cities in the Yellow River Basin using census data. In addition, nighttime light data are widely used in geography, and some scholars have applied nighttime light data as an indicator of urban population vitality instead of population data to measure urban shrinkage [37–39]; i.e., when the change rate of nighttime light value is negative, the city is in a state of shrinkage. Therefore, the study attempts to use nighttime lighting data to validate and supplement the above results of urban shrinkage measured by population data. Figure 5 shows the change rate of urban night light value; 1.9080, 1.7942, 1.8284 and 1.7553 represent the mean value of the nighttime light values of all prefecture-level and county-level cities in corresponding years. As a result, the majority of cities in the Yellow River Basin showed an increase in nighttime light values in 2000–2010 and 2010–2020, with only 3.3% (31 out of 936) of county-level cities in 2000–2010, 3.5% (4 out of 115) of prefecture-level cities and 7.6% (71 out of 936) of county-level cities in 2010–2020 having lower nighttime light values. This conclusion differs significantly from the measurement results of shrinking cities based on population data. Understandably, this study takes ten years as the research period to measure whether cities are shrinking; however, under the background of the rapid development of urbanization in China, the economic development and population vitality of cities also tend to show an upwards trend, even in cities with a declining population. It is clear that applying nighttime light data does not effectively measure shrinking cities on a long time scale. Furthermore, this study compares the mean value of the nighttime light values of the shrinking cities identified in this study (i.e., cities with negative population change rates) with the mean value of the nighttime light values of all cities in the Yellow River Basin. The results show that the mean value of shrinking cities is lower than that of all cities in the Yellow River Basin at the three study points of 2000, 2010 and 2020. From this perspective, the conclusion can demonstrate the reliability of the measurement results of shrinking cities based on population data.

4.2. A Comparison of Typical Patterns of Urban Shrinkage in the Yellow River Basin and Western Developed Countries

The urban shrinkage in the Yellow River Basin forms a typical spatial pattern and differs significantly from that of Western countries. Global shrinkage, central shrinkage and peripheral shrinkage are the three modes describing the pattern of shrinking cities in the Yellow River Basin, with peripheral shrinkage as the primary urban shrinkage mode, representing a pattern of population decrease in urban peripheries (municipal counties) against an increase in urban centers (municipal districts) due to uneven development. However, in Western developed countries, where urbanization is advanced and the difference in the level of economic development within cities is slight, the concept of "peripheralization" is more commonly used at the metropolitan scale to explain the regional spatial structure formed by the migration of many people from the periphery to the center of the metropolitan area [40]. Regarding the urban shrinkage mode, Western scholars have introduced the concepts of doughnut shrinkage and perforated shrinkage, describing the spatial structures of inner cities that have formed doughnut-shaped or perforation-shaped

shrinkage due to deindustrialization and suburbanization. The central shrinkage mode identified in this study is similar to doughnut shrinkage and perforated shrinkage spatially, both describing urban centers that have declined and lost population. However, there are differences in the causes, population destinations and urban impacts of these shrinkage modes. Central shrinkage is driven by lagging development of the urban center, which leads the population to move to other cities and may eventually cause global shrinkage (e.g., Weinan and Bazhong in the Yellow River Basin). Doughnut shrinkage and perforated shrinkage are driven by deindustrialization and suburbanization, leading to population migration to the suburbs, which results in a spatial redistribution of the population between the inner city and the suburbs [41].

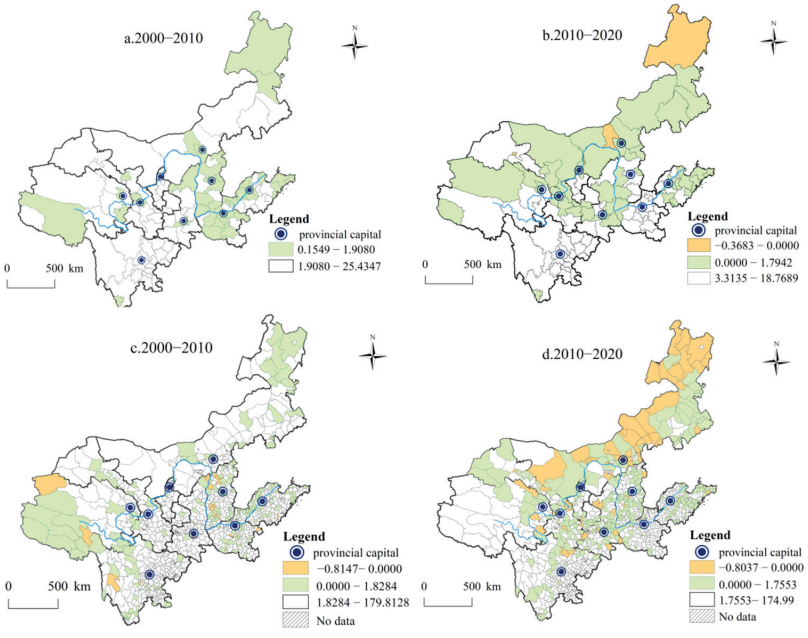


Figure 5. Statistics of night light change rate in cities.

4.3. Analysis of the Influencing Factors of Urban Shrinkage in the Yellow River Basin in the Context of China's Urban Development

The influencing factors of urban shrinkage of the Yellow River Basin closely reflect the characteristics of urban development in China. Demographic change, deindustrialization, suburbanization and globalization are widely recognized as the main drivers of urban shrinkage in developed countries, and these drivers show the same or different effects in the urban shrinkage process in the Yellow River Basin. Unlike the main drivers of urban shrinkage in developed countries, economic development plays a key role in the urban shrinkage of the Yellow River Basin. Similar to the large-scale population movements between developed and less-developed regions during globalization, within the Yellow River Basin, there are distinct migration paths due to the gradient differences in economic development between regions, which are reflected between the upstream, midstream and downstream regions, as well as between the regional center and the regional periphery. This study uses the ageing degree to characterize demographic change. This dominant factor influencing urban shrinkage in developed countries also has a persistent negative effect on the urban shrinkage process in the Yellow River Basin. However, different from the influence of the ageing problem in developed countries, in the Yellow River Basin, the combination of high ageing with accelerated urbanization has a strong influence on cities. This combination prevents cities with low urbanization from experiencing urban shrinkage

in the long term due to the continuous lack of young laborers to build the cities. In addition, deindustrialization and industrial restructuring do not have the same impact on urban shrinkage in the Yellow River Basin as in developed countries, where deindustrialization and the accompanying suburbanization have led to urban shrinkage. In the Yellow River, deindustrialization and industrial restructuring have instead increased the city's attractiveness for a period of time. In addition, due to the difference in urban development stage between the Yellow River Basin and developed countries, suburbanization, as the main driving force of urban shrinkage in developed countries, has not played a significant role in the Yellow River Basin.

In addition, high-speed rail opening, the urban air environment and other regional factors have created significant push-and-pull effects on urban population agglomeration in the Yellow River Basin. In the context of uneven economic development between regions, high-speed railways opening has provided more opportunities for people to migrate to central and developed regions and has led to severe population outflows in peripheral and less-developed regions. In addition, the urban air environment has both a negative and a positive effect on urban population movement. On the one hand, residents' pursuit of a better living environment leads cities with a worse environment to experience urban shrinkage, similar to the cause of suburbanization in developed countries. On the other hand, this phenomenon does not persist in the cities of the Yellow River Basin. Because the gradient of urban development strength is large and the deterioration of the urban air environment is often linked to the level of urban development, people are driven by economic efficiency to ignore environmental problems and stay in these cities. Moreover, the general improvement in the urban air environment in recent years has weakened the negative impact of urban air environment problems. In addition, the natural environment and infrastructure development negatively affect urban shrinkage in the Yellow River Basin; it is intuitively shown that the blind development of urban land and the uncontrolled construction of infrastructure have not led to the return of the urban population but have exacerbated the urban shrinkage phenomenon. This phenomenon is also reflected in the process of urban shrinkage in developed countries. Taking Leipzig and Berlin as an example, there is contradictory development between urban land expansion, facilities construction and population shrinkage [42].

4.4. Urban Shrinkage Brings Opportunities and Challenges to Achieving High-Quality Development

Although the phenomenon of urban shrinkage has received increasing scholarly attention, local governments continue to treat urban shrinkage as a negative phenomenon and neglect it during the period of accelerated urbanization centered on urban growth, and they implement growth-oriented planning to maintain the appearance of urban growth even in shrinking cities with severe population decline. However, this measure can aggravate the phenomenon of urban shrinkage, leading to issues such as increasing housing vacancies and rising crime rates in cities [43]. It is important to note that urban shrinkage is not equal to urban recession and may even bring new development opportunities to cities. Lang introduced the concepts of "concentration" and "peripheralization" to emphasize that urban shrinkage is a result of a social development process that accompanies local spatial concentration [44]. Harrt studied North American shrinking cities as examples, demonstrating that urban depopulation can coexist with economic prosperity [45]. Furthermore, in some shrinking cities, local authorities and planners have begun to emphasize the concept of "smart shrinkage" as opposed to the traditional concept of urban growth, including urban regeneration in Germany [46,47], right-sizing in the USA [48] and the compact city policy in Japan [17]. In the wave of urban growth, it is important for shrinking cities to consider whether to adhere to the traditional "growth orientation" method or adopt the emerging "smart shrinkage" strategy.

5. Conclusions

Using the cities of the Yellow River Basin, this study reveals the types and modes of urban shrinkage under the administrative division system and explores the factors influencing urban shrinkage in the Yellow River Basin from a global perspective and with attention to the local context of urban development in China. The measurement results of urban shrinkage show that the number of shrinking cities at the prefecture and county levels increased in 2000–2010 and 2010–2020. In addition, the degree of urban shrinkage shows a quantitative ranking of "slight shrinkage > severe shrinkage", and the trajectory classification shows a quantitative ranking of "recent shrinkage > worsening shrinkage > slowing shrinkage > steady shrinkage". Based on the spatial pattern of shrinking and nonshrinking cities, there is a typical "core-periphery" pattern in the multiscale administrative divisions in the Yellow River Basin. In terms of influencing factors, economic development strength and speed are the key factors driving urban population change; the ageing degree is also a persistent influencing factor in urban shrinkage; industrial structure transformation has a phased positive effect on urban shrinkage. In addition, high-speed railway opening, the urban natural environment and the facility construction level play a negative role in urban shrinkage. The influence of the urban air environment on the degree of urban shrinkage changes from negative to positive, and its influence on the mode of shrinkage changes from significant to nonsignificant. These conclusions can provide an empirical reference for policy makers to formulate strategies to cope with urban shrinkage.

This article focuses on the cities in nine provinces along the Yellow River Basin and helps reveal the characteristics of urban shrinkage in developing countries. In addition, from the perspective of a river basin, it provides a case study and theoretical support for national and local governments to promote the regrowth and high-quality development of shrinking cities. The study hopes to draw the attention of more scholars and planners to the phenomenon of urban shrinkage, which, as a phase of the urban development process, should not be ignored under the influence of growthism. Creating a "people-oriented" urban development philosophy is the key to retaining the urban population [49]. From this perspective, urban shrinkage can also be an important opportunity for cities to achieve high-quality development.

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References

1. Nelle, A.; Großmann, K.; Haase, D.; Kabisch, S.; Rink, D.; Wolff, M. Urban shrinkage in Germany: An entangled web of conditions, debates and policies. *Cities* **2017**, *69*, 116–123. [CrossRef]
2. Rieniets, T. Shrinking Cities: Causes and Effects of Urban Population Losses in the Twentieth Century. *Nat. Cult.* **2009**, *4*, 231–254. [CrossRef]

3. Lima, M.; Thompson, C.; Aspinall, P. Friendly Communities and Outdoor Spaces in Contexts of Urban Population Decline. *Land* **2020**, *9*, 439. [CrossRef]
4. Lee, J.; Park, Y.; Kim, H. Evaluation of Local Comprehensive Plans to Vacancy Issue in a Growing and Shrinking City. *Sustainability* **2019**, *11*, 4966. [CrossRef]
5. Häußermann, H.; Siebel, W. *Die Schrumpfende Stadt und Die Stadtsoziologie*; Soziologische Stadtforschung: Wiesbaden, Germany, 1988; pp. 78–94.
6. Meng, X.; Long, Y. Shrinking cities in China: Evidence from the latest two population censuses 2010–2020. *Environ. Plan. A Econ. Space* **2022**, *54*, 449–453. [CrossRef]
7. Gunko, M.; Eremenko, Y.; Batunova, E. Planning Strategies in the Context of Urban Shrinkage in Russia: Evidence from Small and Medium-sized Cities. *Mir Ross. Universe Russ.* **2020**, *29*, 121–141.
8. Meng, X.; Jiang, Z.; Wang, X.; Long, Y. Shrinking cities on the globe: Evidence from LandScan 2000–2019. *Environ. Plan. A Econ. Space* **2021**, *53*, 1244–1248. [CrossRef]
9. Wang, R.; Wang, C.; Zhang, S.; Ding, X. A study on the spatial and temporal evolution of urban shrinkage and its influencing factors from a multidimensional perspective: A case study of resource-based cities in China. *PLoS ONE* **2021**, *16*, e0258524. [CrossRef]
10. Yang, Y.; Wu, J.; Wang, Y.; Huang, Q.; He, C. Quantifying spatiotemporal patterns of shrinking cities in urbanizing China: A novel approach based on time-series nighttime light data. *Cities* **2021**, *118*, 103346. [CrossRef]
11. Nuissl, H.; Rink, D. The 'production' of urban sprawl in eastern Germany as a phenomenon of post-socialist transformation. *Cities* **2005**, *22*, 123–134. [CrossRef]
12. Couch, C.; Karecha, J.; Nuissl, H.; Rink, D. Decline and sprawl: An evolving type of urban development–observed in Liverpool and Leipzig. *Eur. Plan. Stud.* **2005**, *13*, 117–136. [CrossRef]
13. Blanco, H.; Alberti, M.; Olshansky, R.; Chang, S.; Wheeler, S.; Randolph, J.; London, J.; Hollander, J.; Pallagst, K.; Schwarz, T.; et al. Shaken, shrinking, hot, impoverished and informal: Emerging research agendas in planning. *Prog. Plan.* **2009**, *72*, 195–250. [CrossRef]
14. Thompson, E.; de Beurs, K. Tracking the removal of buildings in rust belt cities with open-source geospatial data. *Int. J. Appl. Earth Obs. Geoinf.* **2018**, *73*, 471–481. [CrossRef]
15. Pallagst, K. The planning research agenda: Shrinking cities—A challenge for planning cultures. *Town Plan. Rev.* **2010**, *81*. [CrossRef]
16. Özatağan, G.; Eraydın, A. The Role of Government Policies and Strategies Behind the Shrinking Urban Core in an Expanding City Region: The Case of Izmir. *Eur. Plan. Stud.* **2014**, *22*, 1027–1047. [CrossRef]
17. Usui, H.; Perez, J. Are patterns of vacant lots random? Evidence from empirical spatiotemporal analysis in Chiba prefecture, east of Tokyo. *Environ. Plan. B Urban Anal. City Sci.* **2022**, *49*, 777–793. [CrossRef]
18. Ma, Q.; Gong, Z.; Kang, J.; Tao, R.; Dang, A. Measuring Functional Urban Shrinkage with Multi-Source Geospatial Big Data: A Case Study of the Beijing-Tianjin-Hebei Megaregion. *Remote Sens.* **2020**, *12*, 2513. [CrossRef]
19. Karp, D.; Bagchi-Sen, S.; Rogerson, P. Not all shrinking places are similar: The variegated nature of population decline in the United States. *Appl. Geogr.* **2022**, *138*, 102581. [CrossRef]
20. Mallach, A.; Haase, A.; Hattori, K. The shrinking city in comparative perspective: Contrasting dynamics and responses to urban shrinkage. *Cities* **2017**, *69*, 102–108. [CrossRef]
21. Martinez-Fernandez, C.; Audirac, I.; Fol, S.; Cunningham-Sabot, E. Shrinking cities: Urban challenges of globalization. *Int. J. Urban Reg. Res.* **2012**, *36*, 213–225. [CrossRef]
22. Li, J.; Zhang, H.; Sun, Z. Spatiotemporal variations of land urbanization and socioeconomic benefits in a typical sample zone: A case study of the Beijing-Hangzhou Grand Canal. *Appl. Geogr.* **2020**, *117*, 102187. [CrossRef]
23. Niu, W.; Xia, H.; Wang, R.; Pan, L.; Meng, Q.; Qin, Y.; Li, R.; Zhao, X.; Bian, X.; Zhao, W. Research on Large-Scale Urban Shrinkage and Expansion in the Yellow River Affected Area Using Night Light Data. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 5. [CrossRef]
24. Jin, Z.; Wang, C.; Yu, S.; Zhang, S.; Ding, X. Spatiotemporal evolution and influencing factors of urban shrinkage in the Yellow River Basin, China. *PLoS ONE* **2022**, *17*, e0264236. [CrossRef]
25. Haase, A.; Bernt, M.; Großmann, K.; Mykhnenko, V.; Rink, D. Varieties of shrinkage in European cities. *Eur. Urban Reg. Stud.* **2016**, *23*, 86–102. [CrossRef]
26. Wolff, M.; Wiechmann, T. Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990–2010. *Eur. Urban Reg. Stud.* **2018**, *25*, 122–139. [CrossRef]
27. Segers, T.; Devisch, O.; Herssens, J.; Vanrie, J. Conceptualizing demographic shrinkage in a growing region–Creating opportunities for spatial practice. *Landsc. Urban Plan.* **2020**, *195*, 103711. [CrossRef]
28. Yang, Z.; Dunford, M. City shrinkage in China: Scalar processes of urban and hukou population losses. *Reg. Stud.* **2018**, *52*, 1111–1121. [CrossRef]
29. Zhang, Y.; Fu, Y.; Kong, X.; Zhang, F. Prefecture-level city shrinkage on the regional dimension in China: Spatiotemporal change and internal relations. *Sustain. Cities Soc.* **2019**, *47*, 101490. [CrossRef]
30. Guo, F.; Qu, X.; Ma, Y.; Tong, L. Spatiotemporal pattern evolution and influencing factors of shrinking cities: Evidence from China. *Cities* **2019**, *119*, 103391. [CrossRef]

31. Wang, S.; Guo, J.; Luo, X.; Liu, J.; Gu, Z. Spatial Impact of High-speed Railway on the Urban Scale:An Empirical Analysis from Northeast China. *Chin. Geogr. Sci.* **2020**, *30*, 366–378. [CrossRef]
32. Guan, D.; He, X.; Hu, X. Quantitative identification and evolution trend simulation of shrinking cities at the county scale, China. *Sustain. Cities Soc.* **2021**, *65*, 102611. [CrossRef]
33. Chen, Z.; Yu, B.; Yang, C.; Zhou, Y.; Yao, S.; Qian, X.; Wang, C.; Wu, B.; Wu, J. An extended time series (2000–2018) of global NPP-VIIRS-like nighttime light data from a cross-sensor calibration. *Earth Syst. Sci. Data* **2021**, *13*, 889–906. [CrossRef]
34. Liu, C.; Yang, P. A Comparative Study on the Motivation Mechanism and Performance Characteristics of Chinese and Foreign Shrinking Cities. *Mod. Urban Res.* **2017**, *24*, 64–71. [CrossRef]
35. Deng, T.; Wang, D.; Yang, Y.; Yang, H. Shrinking cities in growing China: Did high speed rail further aggravate urban shrinkage? *Cities* **2018**, *86*, 210–219. [CrossRef]
36. Song, X.; Feng, Q.; Xia, F.; Li, X.; Scheffran, J. Impacts of changing urban land-use structure on sustainable city growth in China: A population-density dynamics perspective. *Habitat Int.* **2021**, *107*, 102296. [CrossRef]
37. Yang, D.; Luan, W.; Yang, J.; Xue, B.; Zhang, X.; Wang, H.; Pian, F. The contribution of data-driven poverty alleviation funds in achieving mid-21st-Century multidimensional poverty alleviation planning. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 179. [CrossRef]
38. Dong, B.; Ye, Y.; You, S.; Zheng, Q.; Huang, L.; Zhu, C.; Tong, C.; Li, S.; Li, Y.; Wang, K. Identifying and Classifying Shrinking Cities Using Long-Term Continuous Night-Time Light Time Series. *Remote Sens.* **2021**, *13*, 3142. [CrossRef]
39. You, H.; Yang, J.; Xue, B.; Xiao, X.; Xia, J.; Jin, C.; Li, X. Spatial evolution of population change in Northeast China during 1992–2018. *Sci. Total Environ.* **2021**, *776*, 146023. [CrossRef]
40. Ribant, M.; Chen, X. A typology of U.S. Shrinking Cities. *Prof. Geogr.* **2020**, *72*, 152–164. [CrossRef]
41. Schetke, S.; Haase, D. Multi-criteria assessment of socio-environmental aspects in shrinking cities. Experiences from eastern Germany. *Environ. Impact Assess. Rev.* **2007**, *28*, 483–503. [CrossRef]
42. Dubeaux, S.; Sabot, E. Maximizing the potential of vacant spaces within shrinking cities, a German approach. *Cities* **2018**, *75*, 6–11. [CrossRef]
43. Batunova, E.; Gunko, M. Urban shrinkage: An unspoken challenge of spatial planning in Russian small and medium-sized cities. *Eur. Plan. Stud.* **2018**, *26*, 1580–1597. [CrossRef]
44. Lang, T. Shrinkage, Metropolization and Peripheralization in East Germany. *Eur. Plan. Stud.* **2012**, *20*, 1747–1754. [CrossRef]
45. Hartt, M. The diversity of North American shrinking cities. *Urban Stud.* **2018**, *55*, 2946–2959. [CrossRef]
46. Radzimski, A. Involving small landlords as a regeneration strategy under shrinkage: Evidence from two East German cases. *Eur. Plan. Stud.* **2017**, *26*, 526–545. [CrossRef]
47. Knippschild, R.; Zöllter, C. Urban Regeneration between Cultural Heritage Preservation and Revitalization: Experiences with a Decision Support Tool in Eastern Germany. *Land* **2021**, *10*, 547. [CrossRef]
48. Coppola, A. Projects of becoming in a right-sizing shrinking City. *Urban Geogr.* **2019**, *40*, 237–256. [CrossRef]
49. Franklin, R. The demographic burden of population loss in US cities, 2000–2010. *J. Geogr. Syst.* **2019**, *23*, 209–230. [CrossRef]

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Human Activity Intensity in China under Multi-Factor Interactions: Spatiotemporal Characteristics and Influencing Factors

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Abstract: Human activities involving nature have various environmental impacts. The assessment of the spatial and temporal evolution of human activity intensity (HAI) and its driving forces is significant for determining the effects of human activities on regional ecological environments and regulating such activities. This research quantified the HAI of China, assessed its spatiotemporal characteristics, and analyzed its influencing factors based on the land use data and panel data of 31 provinces in mainland China. The results indicate that the HAI in China is increasing, with the average value increasing from 15.83% in 1980 to 20.04% in 2018, and the HAI was relatively serious in the Beijing–Tianjin–Hebei region, Yangtze River Delta and Pearl River Delta in this period. The spatial differences in the HAI in China show a pattern of being strong in the east and weak in the west, and the spatial center of gravity of China's HAI has gradually moved west, changing from a central enhancement mode to a point-like "core" enhancement mode. The dominant factors affecting spatial differences in HAI are economic and industrial levels. Labor, population, and capital factors also strongly impact HAI, and energy consumption and pollution emissions have little impact. These results deepen the understanding of the underlying mechanism of the environmental impact of human activities and provide a scientific basis for land-use-related decision making and eco-environment construction.

Keywords: human activity; multi-factor interactions; spatiotemporal characteristics; geographical detector model

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1. Introduction

Human activity is a series of actions imposed on the ecosystem by human beings for their own development needs and is a relatively broad concept that includes humans' exploitation of land resources, use of natural resources, and environmental protection activities [1]. The impact of such human activity on ecosystems is best reflected by land use type. This impact is further reflected in the industrialization and urbanization of each country. Research shows that human activity is driving economic development worldwide [2]. For example, the urbanization rate in China increased by 41.95% from 1978 to 2018, making it one of the fastest growing countries in the world. However, an increasing number of studies also confirm that continued urbanization and industrialization mean that human demand for land resources is increasing [3,4]. In this context, the increasing ability of humans to transform nature has brought enormous pressure to the ecosystem, making the originally fragile ecological environment deteriorate continuously [5,6]. If human activities are not effectively controlled, there will be a serious threat to global ecological

security and sustainable development. Therefore, the quantitative and spatial expression of human activity intensity (HAI) is the basis for evaluating the impact of human activities on the ecological environment and provides a theoretical basis for the rational utilization of land resources and eco-environment protection planning [7,8].

As noted, human activity is the relatively broad concept of a series of behaviors imposed by human beings on the environment for their own development needs. The concept of human activity can be traced back to the 18th century [9], but the evaluation and measurement of HAI started later and has led to a variety of measurement methods [10,11]. The large-scale measurement of human activities began in 1994. Hannah et al. [12] measured the degree of human interference with the global natural habitat. Past research shows that most habitable areas have been affected by human activities. In the 21st century, scholars have conducted more in-depth research on human activities, and their measurement methods and research subjects have become more diverse. These measurement methods are mainly divided into two groups. On the one hand, based on the changes caused by humans themselves and the environmental changes caused by human activities [13,14], Magalhães et al. [15] and Roth et al. [16] constructed a human activity index system based on the overlay analysis of multiple indicators. The research shows that human activities destroy local lands and ecosystems. On the other hand, the land surface environment is constantly affected or even altered by human activities, resulting in changed land use types. This means that land use change can reflect human activity intensity [17]. In recent years, Xu et al. [18] have widely recognized the construction land equivalent of various land use types as a way to measure HAI. This method can eliminate regional differences and accurately measure a wide range of regions with different spatial characteristics. In terms of research content, at this stage, the research on human activities has achieved good interaction with the fields of ecological environment, climate and social development, which can be used to explore the comprehensive situation of cities [19]. For example, Sun et al. [20] measured HAI on the Qinghai–Tibet Plateau and combined it with the value of ecosystem services, concluding that HAI on the Qinghai–Tibet Plateau increased slightly and that the ecosystem was basically stable. Zhang and Xu [21] believe that HAI interacts strongly with local production life ecological functions, which is an important factor affecting regional sustainable development. Chen et al. [22] took the POI data of Shanghai, China as a measurement standard to explore the relationship between HAI and night light. Although the measurement methods and research areas related to HAI differ, their purpose is consistent: to regulate regional ecological pressure and realize regional sustainable development.

To date, scholars have conducted extensive research on human activities. However, the existing research on human activity offers only an insufficient analysis and mainly focuses on temporal and spatial changes in human activities and the interactions between human activities and a single area of environmental concern [23–25]. On the one hand, there is a lack of comparative research on large-scale regions; on the other hand, there are few studies on the influencing factors of HAI or that use multiangle analysis, most studies use traditional methods for analysis. It is difficult to quantify the effect of single factors on human activities using traditional linear regression and correlation analysis methods. This is because the relationship between two variables may be affected by other factors. Compared with other correlation analysis methods, the geographical detector method (GDM) effectively identifies the contribution of a single factor and the interaction among influencing factors and better solves the effects of spatial location. Many study fields have begun to use GDM to quantify the influence of factors explaining the temporal and spatial evolution of geographical phenomena. For example, GDM has been used in the study of air pollution [26], built-up land expansion [27], and agricultural [28] and human health [29]. Given this, we use the geographical detector technique in this paper to explore HAI under the influence of multiple factors. This paper aims to explore the factors involved in HAI changes in the situation of rapid socioeconomic development in China since the reform and opening-up began and to analyze the reasons for the regional differentiation of human

activities so as to help control human activities, achieve sustainable development, and effectively alleviate the tension between humans and the land, which is very significance for maintaining the stability of the ecosystem and high-quality development.

2. Data and Methodology

2.1. Conceptual Framework

The main purposes of this paper are to explore the regional differences and the changing rules of human activity intensity in mainland China and to identify the impact of influencing factors on human activity intensity in China. First, we measure the intensity of human activities from 1980–2018 by using ArcGIS 10.6 software based on land use data and construction land equivalent conversion coefficients. Second, the time-space pattern of human activity intensity is explored from multiple perspectives. Third, influencing factors are identified based on related studies. Finally, the interactive effect of each influencing factor on human activity intensity is studied based on the geographic probe approach. The technical framework of the study is illustrated in Figure 1.

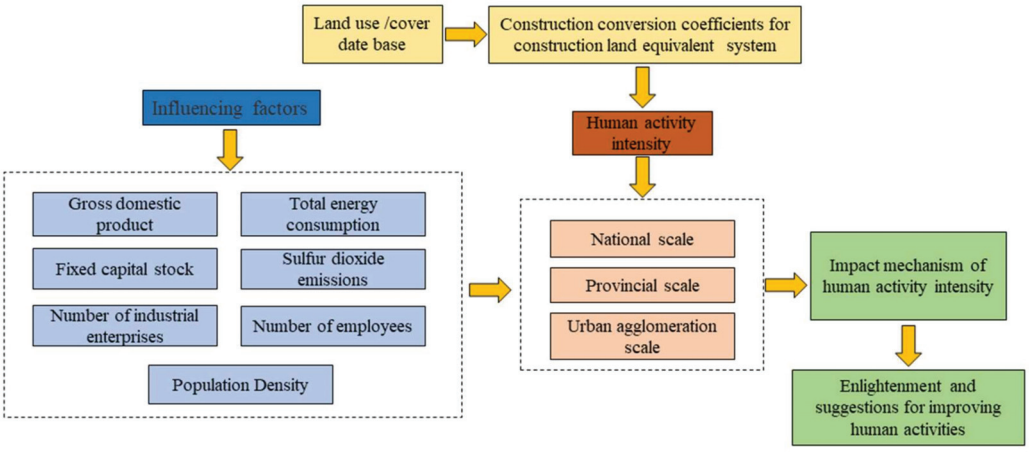


Figure 1. The technical framework of the study.

2.2. Data Sources

This study takes 31 provincial administrative regions in China as the research object. According to existing research, in areas with a better level of economic development, human exploitation of the land and disturbance of the ecological environment are more intense than in other areas. Therefore, we choose China's three major economic centers (Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta) as the subjects of our study at the city cluster scale [30]. The comparison of these regions can help in analyzing whether economically developed regions are taking measures to control human activities. The resolution of the land use data involved in the study is 30 m, which comes from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (http://www.resdc.cn/, accessed on 29 November 2021). The socioeconomic statistical data are mainly from the China Statistical Yearbook, China Energy Statistical Yearbook, China Urban Statistical Yearbook and provincial statistical yearbooks. Among them, the data of total energy consumption of Tibet and Hainan in 1990, and the data of fixed capital stock of some cities in 1983 and 1987 are missing. The missing panel data are obtained by data interpolation of adjacent years.

2.3. Identification of Influencing Factors

The identification of factors influencing HAI is a complex task. By referring to relevant research literature [21,31,32], it is known that human activities are generally related to

urbanization, population, industrial activities, agricultural activities, economic activities, energy consumption. Therefore, we based on 31 provincial administrative regions comprehensively and consider the changes in human activities in China. We selected influencing variables referring to economic, capital, industrial, energy consumption, pollution, labor, and demographic factors as indicators to explore the changes in HAI. Considering that arable land is one of the land use types, its area is the basis for assessing HAI, and the resources consumed by human for agricultural activities are less. Therefore, this study did not consider agricultural activities as one of the influencing factors for human activity intensity. Table 1 shows statistical information for each of the variables.

Table 1. Statistical summary of the influencing factors.

Indicator Category	Variables	Definitions	Units	Data Sources
Economic factors	GDP	Regional gross domestic product	100 million yuan	China statistical yearbook
Capital factors	FCS	Fixed capital stock	100 million yuan	China statistical yearbook
Industrial factors	NIE	Number of industrial enterprises	pieces	China industry statistical yearbook
Energy factors	TEC	Total energy consumption	10^4 tons of standard coal	China energy statistical yearbook
Pollution factors	SUL	Sulfur dioxide emissions	10^4 tons	China statistical yearbook on environment
Labor factors	NE	Number of employees	10^4 people	Provincial statistical yearbook
Demographic factors	PD	Population Density	people/km^2	China statistical yearbook

(1). Economic factors. Regional GDP is a macro indicator used to measure the level of national or regional economic development, and it is also one of the most common and important standards for measuring development. Economic development is the main purpose of human activities. There may be ecological and environmental problems caused by human activities that prioritize the speed of economic development over other effects. Therefore, economic factors, represented by regional GDP, are regarded as one of the factors affecting HAI.

(2). Capital factors. Capital factors are an important index affecting industrial structure. Reasonable capital flow is not only the basis and premise of realizing the optimization of economic and industrial structure but also a factor that affects HAI. To accurately measure the impact of capital factors on human activities, this paper uses the perpetual inventory method to calculate the fixed capital stock. Referring to the calculation methods of Li [33] and Wu [34], this paper selects the depreciation rate of fixed assets in corresponding provinces, makes a reduction based on 1980, and finally, obtains the fixed capital stock.

(3). Industrial factors. The number of industrial enterprises can reflect the industrial scale of a region. It is an important indicator of the degree of regional industrialization and significantly affects the development of land by human activities. Therefore, the number of industrial enterprises is regarded as one of the indicators affecting HAI.

(4). Energy consumption factors. Under the current international trend of "carbon peaking and carbon neutralization", China is facing the dual pressures of ensuring energy supply and protecting the ecological environment, and the impact of energy factors on regional economies and industries is becoming increasingly serious. Although controlling the total energy consumption will limit economic development to a certain extent, it is conducive to reducing carbon emissions and controlling HAI [35]. Therefore, we take the total energy consumption, representing energy factors, as one of the influencing factors to detect HAI.

(5). Pollution factors. Sulfur dioxide emitted in the process of industrial production is the main source of pollution; such pollution factors can reflect the type and scale of

regional industries. An excessive intensity of human activities will inevitably lead to an increase in regional pollutants. Therefore, sulfur dioxide emissions are selected as an influencing factor of HAI.

(6). Labor factors. Regional economic development and industrial enterprise production inevitably require a large labor force. A reasonable labor force distribution among regions is conducive to the allocation of market resources and the adjustment of HAI. Therefore, the number of employees is selected to represent the impact of labor factors on HAI.

(7). Demographic factors. China has the largest population of any country in the world. As population size is the main body of HAI [36], population density is selected as an influencing factor of HAI.

2.4. Methodology

2.4.1. Human Activity Intensity Model

Human activity intensity is an indicator that reflects the strength of human activity in a certain area through the land use type. The formula of the HAI model is:

$$S_j = \sum_{i=1}^{n} (S_i \cdot C_i) \quad (1)$$

$$\mathrm{HAI} = \frac{S_j}{S} \times 100\% \quad (2)$$

where HAI is the value of human activity intensity; S_j is the area of equivalent construction land; S_i is the area of the ith land use type in the study area; S is the total area of the study area; and n is the number of land use types; C_i is the coefficient of construction land equivalent converted by the ith land use type, which are time-invariant. This means that the same coefficients were used for one land use type during the study period.

In this study, we refer to the Xu, Xu and Tang [18] index system of construction land to equate to different land use types. The system is constructed by a step-by-step two-level algorithm used to characterize the degree of interference of human activities on various types of land. The advantage of this method is that it provided refined classification standards. Regional differences caused by the vast size of China's territory have been eliminated as much as possible. In addition, we use ArcGIS 10.6 to calculate HAI on 10-km grid units to show regional differences. HAI in various provinces in China is divided into five levels using the natural breakpoint method: very low (less than 5%), low (5–12%), medium (12–19%), high (19–26%) and very high (more than 26%).

2.4.2. The Standard Deviational Ellipse Method

Standard deviational ellipse (SDE) analysis is a method for measuring the spatial distribution of a set of points or areas by calculating the standard distance separately in the x and y directions [37]. The spatial distribution law and evolution trend of geographical elements are quantitatively described by taking the center of gravity, azimuth and primary and secondary coordinate axes of the ellipse as parameters [38]. The larger the value difference between the primary and secondary coordinate axes, the more obvious the directionality of geographical elements. This study uses the standard deviation ellipse to explore the spatial characteristics of HAI changes from multiple angles [39]. The standard deviation ellipse is calculated as follows:

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}, \overline{Y} = \frac{\sum_{i=1}^{n} y_i}{n} \quad (3)$$

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \overline{X})^2}{n}}, SDE_y = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \overline{Y})^2}{n}} \quad (4)$$

where $\overline{X}$ and $\overline{Y}$ represent the coordinates of the spatial barycenter for the HAI; x_i and y_i are the longitude and latitude of each subregion i, respectively; and n is the total number of

study areas. SDE_x and SDE_y represent the major and minor axes of the ellipse. By using the *SDE* method in ArcGIS 10.6, the directivity of the spatial distribution of HAI can be visualized.

2.4.3. Geographic Detector Method (GDM)

The GDM is a new spatial statistical method that is mainly used to detect spatial differentiation in the ecological and geographical sense [40]. This paper uses single factor detection and factor interaction detection in GDM to analyze the human activities intensity in 31 provincial administrative regions of China and reveals the influence degree and coupling interaction of each factor. This means that if a factor is associated with human activity intensity, the spatial distribution of human activity intensity is similar to the spatial distribution of that factor. The calculation formula is [41]:

$$q = 1 - \frac{1}{Kw^2}\sum_{n=1}^{M} K_n w_n^2 \quad (5)$$

where q is the power of the determinant, and its value is within the range [0,1]. K and K_n represent the number of study areas and the number of units in the divided study area, respectively, M represents the number of index samples, and w^2 and w_n^2 represent the variance of the study area and the variance of the subareas, respectively.

Factor interaction detection refers to evaluating the impact of the joint action of two factors on the level of human activities by judging the interaction between two factors in all detection factors. The interaction between two factors can be divided into the following five types (Table 2).

Table 2. The possible interaction between two variables and their interactive impacts.

Interaction Relationship	Interaction Type
$q(X_1 \cap X_2) < \min(q(X_1), q(X_2))$	nonlinear weaken
$\min(q(X_1), q(X_2)) < q(X_1 \cap X_2) < \max(q(X_1), q(X_2))$	Un-weaken each other
$q(X_1 \cap X_2) > \max(q(X_1), q(X_2))$	bi-enhance
$q(X_1 \cap X_2) > q(X_1) + q(X_2)$	nonlinear enhance
$q(X_1 \cap X_2) = q(X_1) + q(X_2)$	independent

3. Results

3.1. Characteristics of Human Activity Intensity in China

3.1.1. Temporal and Spatial Characteristics of Human Activity Intensity in China

Figure 2 shows that the HAI in China exhibited an upward trend from 1980 to 2018. Indeed, the HAI in China increased from 15.27% in 1980 to 18.42% in 2018, an increase of 20.60%; the growth rate from 2000 to 2010 was the largest. In 1980, the equivalent area of construction land was 69.93 $\times$ 10^4 km^2, and this increased to 78.38 $\times$ 10^4 km^2 by 2018, with the largest increase, 4.05 $\times$ 10^4 km^2, happening between 2010 and 2018. The results indicate that the highest annual average HAI concentration in the Beijing–Tianjin–Hebei region in the three major economic growth poles reached 32.18% in 2010, and the HAI situations in the Beijing–Tianjin–Hebei region and Yangtze River Delta were the most serious. The HAI in the Pearl River Delta is relatively weak, but it is still significantly higher than the national average. Interestingly, the Beijing–Tianjin–Hebei region saw a slight decline after 2010, but the Yangtze River Delta region rose significantly.

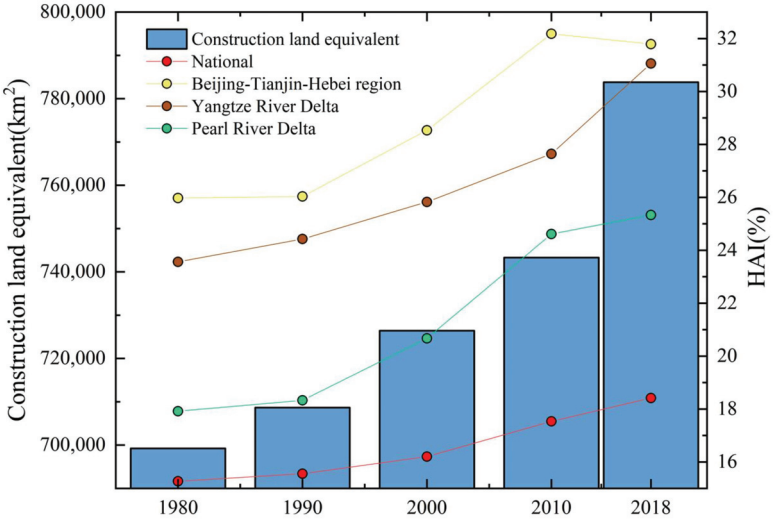


Figure 2. Construction land equivalent area and average HAI from 1980 to 2018.

Spatially, the HAI in China varied greatly between the east and west from 1980 to 2018 (Figure 3), showing a decreasing trend from the eastern coastal area to the inland area. The increasing trend is mainly due to a gradual increase in the eastern coastal area and the expansion around the Beijing–Tianjin–Hebei urban agglomeration. The number of provinces with very high HAI levels changed notably, increasing from three provinces in 1980 to nine in 2018, and gradually became concentrated in space. Among these provinces, Tianjin, Jiangsu and Shanghai have consistently reached the very high HAI level.

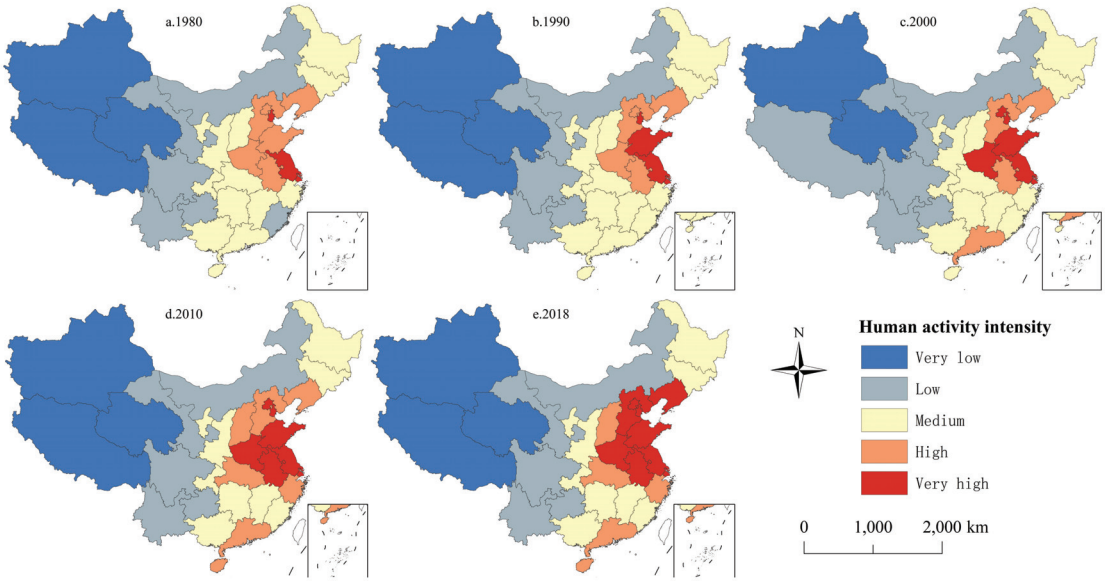


Figure 3. Spatial distribution of human activity intensity in China from 1980 to 2018.

The HAI in Shandong and Fujian increased from 1980 to 1990, and Fujian's role in supporting the reform and opening-up policy was initially obvious. During this period,

Shandong's agriculture and industry developed rapidly, and the total economic output value jumped to second highest in the country, reflecting how economic, agricultural and industrial activities increase the intensity of regional human activities to varying degrees. As China's political center and most populous province, Beijing and Henan, respectively, reached the very high HAI level in 2000. In 2010, human activities in Hubei, Anhui and Zhejiang reached the high or very high HAI levels; these three provinces are in the Yangtze River Basin, indicating that significant changes took place in the Yangtze River Basin during this period, and the rapid expansion of cities and towns caused by key development was the main factor for the increase in human activities there. In 2018, the Bohai Rim region saw concentrated changes in human activities. Liaoning and Hebei reached the very high HAI level, and Beijing and Tianjin both decreased slightly, but they were still at the very high HAI level. In 2017, China established a national new area, the Hebei Xiong'an New Area. The change in policies led to the large-scale development of land in the Xiong'an New Area, which led to the rise of surrounding industries, sharing the pressure of Beijing and Tianjin.

3.1.2. Evolutionary Characteristics of Human Activity Intensity in China

To explore the evolution of HAI in China in greater depth, we calculate the change in HAI on a 10-km grid unit and reveal the evolution of human activity combined with a standard deviation ellipse method (Figure 4) to comprehensively explore the temporal and spatial evolution process of such activities.

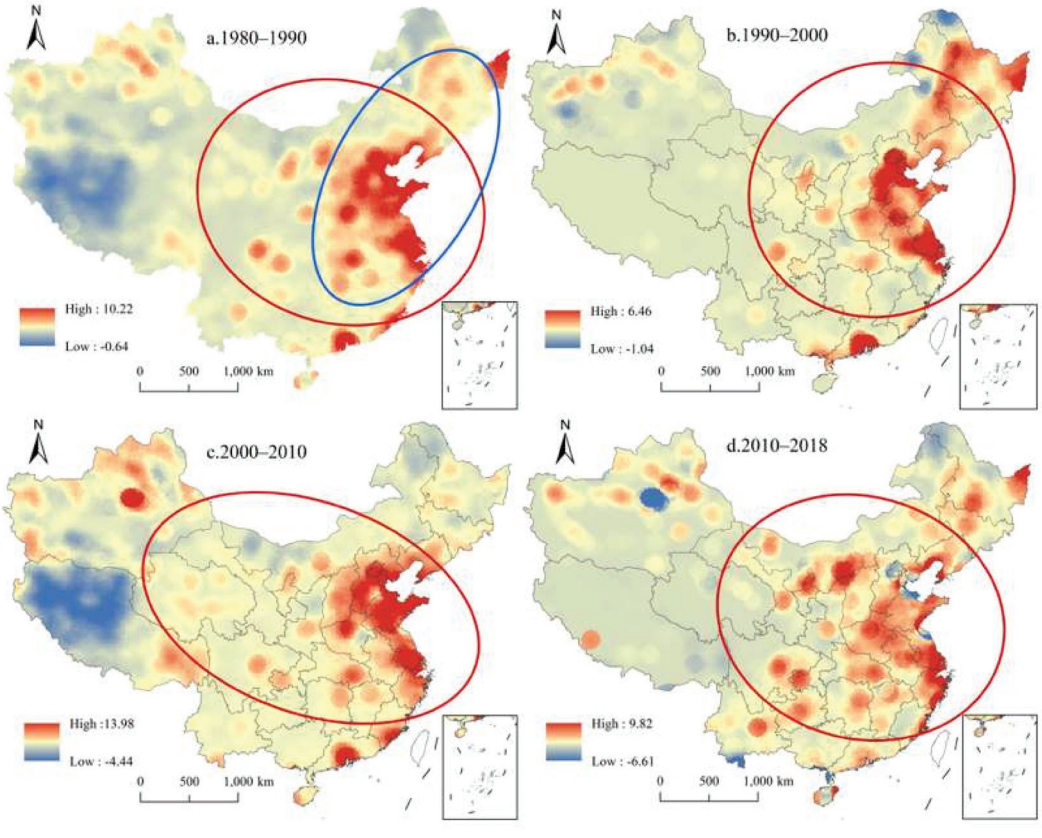


Figure 4. Spatial changes in human activity intensity in China from 1980 to 2018.

From 1980 to 1990, the polarization of HAI in China was significant (Figure 4a). The regions with enhanced human activities were mainly concentrated on the eastern coast, Heilongjiang and eastern Hubei Province, showing a significant east-northeast distribution; there were no significant changes in other regions. During this period, the maximum increment of the HAI level reached 10.22%, but the average increment was only 0.15%, which was the lowest value across the entire period. Therefore, the areas where human activities increased from 1980 to 1990 were significantly different from other areas. The standardized ellipse from 1990 to 2000 shows that the region with enhanced human activities extended westward and inland (Figure 4b). The Beijing–Tianjin–Hebei Urban Agglomeration, the Pearl River Delta and the Yangtze River Delta are the most important economic regions in China, and their human activity levels led to them having the largest increments of all regions in this decade (Figure 4c). In turn, this indicates that after the initial vigorous development of economic activities such as foreign trade in coastal areas, China's human activities became relatively balanced in that decade. From 2000 to 2010, the HAI in China showed a northwest-southeast distribution (Figure 4d). The areas with increased HAI extend to the western inland areas. In comparison, the HAI in western Tibet decreased and those in eastern Tibet increased. The dot growth mode of HAI began to show, and the human activities in Northeast China were basically stable. From 2010 to 2018, the standardized ellipse was distributed in the east-west direction. It is worth noting that the HAI in the Beijing–Tianjin–Hebei Urban Agglomeration and the Yellow River Delta of Shandong decreased slightly, which shows that these areas successfully controlled human activity intensity. In addition, the HAI decreased slightly in southern Yunnan and the Leizhou Peninsula, indicating that the relatively economically backward areas were also affected by a variety of reasons that led to a decrease in human activity. On the whole, the central effect of the enhancement of human activities weakened, and the point distribution mode became more significant.

3.2. Analysis of Influencing Factors

3.2.1. Single Factor Detection Analysis

In this section, we use the geographical detector method to identify the driving factors and their determinant power (q) on HAI. For a more intuitive comparison of q values in all years, the results for the 7 factors are illustrated in a box-whisker plot (Figure 5). The results of single factor detection analysis show that all factors play a driving role in human activities in China to a certain extent, and the power of determinant values can reflect the decisive level of the change in HAI driven by the detected factors. From 1980 to 2018, based on their determinant power, the influencing factors can be ranked as follows in descending order: GDP > NIE> PD > NE > FCS > TEC > SUL.

According to the detected results during the study period, the GDP factor generated a q value from 0.463 to 0.557, indicating a significantly high determinant power of regional gross domestic product on HAI, and economic factors were the main reasons for the regional differences in HAI. To a certain extent, the economic gap between eastern and western China leads to differences in human activities, resulting in the rapid increase in human activities in the eastern region and the slow change in the western region. Among other variables, the determinant power levels of NIE, PD, NE and FCS were ranked second, third, fourth and fifth, respectively. The difference between the four q levels was small. Interestingly, the determinant power level of PD had narrow interquartile ranges and was always high without obvious fluctuation, which indicates that the spatial heterogeneity of HAI was stably influenced by population density. TEC and SUL had relatively wide interquartile ranges, and the determination power level is small and significantly lower than that of other detected factors. In terms of time, the power of the determination level of the two decreased significantly from 2000 to 2010, indicating that TEC and SUL had little impact on human activities.

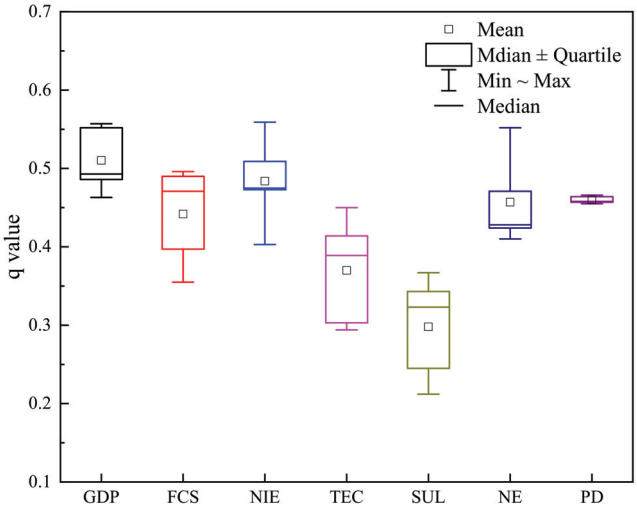


Figure 5. The determinant power (*q*) for the 7 factors guiding the human-activity intensity effect.

3.2.2. Multiple Factor Interaction Detection Analysis

The results show that the interaction of any two factors from 1980 to 2018 was greater than the effect of a single factor on human activities (Figure 6). Most of the interactions enhanced the effect of each factor, and most demonstrated nonlinear enhancement and bi-enhancement. This indicates that the comprehensive consideration of multiple driving factors and their interactions can reveal the reasons for the spatial differentiation of HAI more clearly than studying single influencing factors alone.

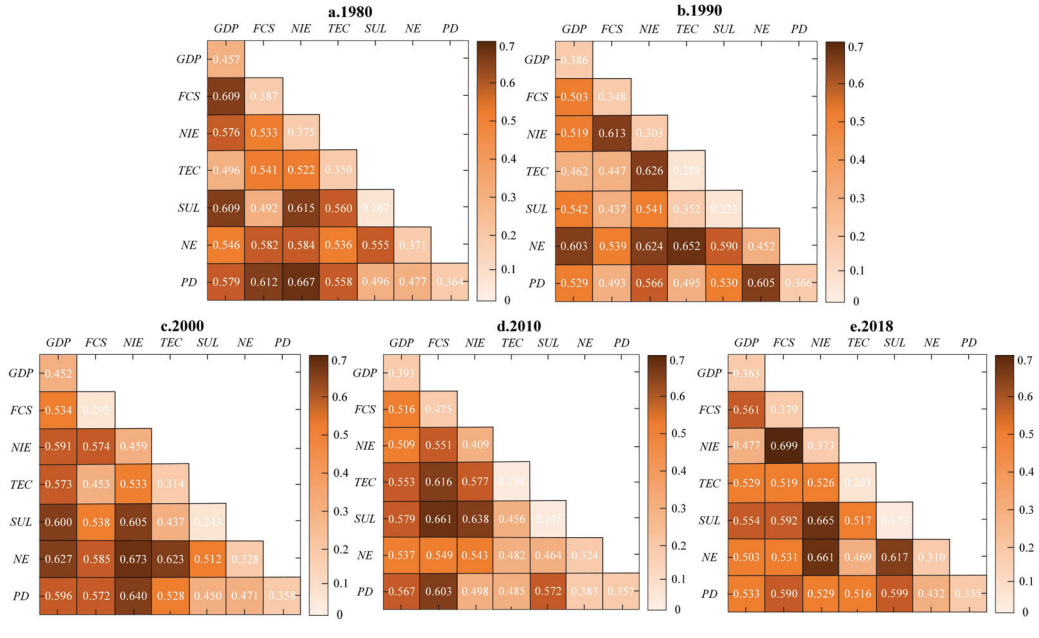


Figure 6. The *q* values of interactions between factors affecting human activity intensity.

In 1980, NIE ∩ PD had the most obvious impact on HAI. The q value of interaction detection was as high as 0.667, and the determinant was nearly 67%. In addition, the factors with an impact of more than 60% on HAI included GDP ∩ FCS, GDP ∩ SUL, FCS ∩ PD and NIE ∩ SUL. In 1990, TEC ∩ NE had the strongest impact on HAI, with a decisive force of approximately 65%. Factors with an interaction degree of more than 60% included GDP ∩ NE, FCS ∩ NIE, NIE ∩ TEC, NIE ∩ NE and NE ∩ PD. In 2000, NIE ∩ NE had the strongest decisive power, approximately 68%, followed by NIE ∩ PD, with a decisive power of approximately 64%. Factors with a decisive power of more than 60% also included GDP ∩ SUL, GDP ∩ NE and NIE ∩ SUL. In 2010, the most significant interaction factor affecting HAI was FCS ∩ SUL, with a q value of 0.661 and a determinant of approximately 66%. In addition, the determinants of FCS ∩ TEC, FCS ∩ PD and SUL ∩ NIE were also greater than 60%. In 2018, FCS ∩ NE had the strongest impact on HAI in China, with the decisive power of interactive detection being approximately 70% and the decisive power of FCS ∩ NIE and NIE ∩ SUL on HAI being more than 65%.

Based on the above results, it can be seen that there are differences in the interaction and coupling of factors in different periods. For example, the interaction between economic and demographic factors was the strongest in 1980, the interaction between labor factors and industrial factors was the strongest in 1990–2000, the interaction between capital factors was the strongest in 2010, and the interaction between industrial factors was the strongest in 2018. On the whole, the interaction between industrial factors and other factors was the strongest; that is, the strength of human activities was more vulnerable to interference by industrial factors, resulting in regional differentiation.

4. Discussion

4.1. Implications of Human Activity Intensity

HAI is a comprehensive indicator of human impact on land development. Exploring the temporal and spatial evolution of HAI can help comprehensively evaluate the role of human activities on regional land and the environment by taking the evolution as a basis for coordinating the layout from local to overall to regulate human activities. We comprehensively evaluated HAI in China from 1980 to 2018. Unlike existing studies [32–44], this paper comprehensively considers multiple dimensions of HAI changes and reveals the spatial heterogeneity of such changes. Although the HAI in the Yangtze River Delta in 2018 was slightly lower than that of the Beijing–Tianjin–Hebei region, its growth trend in the Yangtze River Delta was steeper. Evidence has shown that in the Yangtze River Delta, rapid urbanization intensifies the trend toward land fragmentation and promotes the rapid expansion of construction land [45].

During the study period, HAI in China generally increased, and the changing trends in various regions or provinces varied greatly. For example, from a regional perspective, Northeast China was an important mineral resource center and industrial center in China in the 30 years after the founding of the People's Republic of China. Human interference in the region was extremely frequent. Before 2000, heavy industry had not yet declined, and human activities were still increasing. In particular, human activities in Heilongjiang increased greatly during that period, but after 2000, the development focus shifted south. The northern coast of Liaoning has become the main area in Northeast China for increased human activities. The coastal areas in northern Shandong are mainly caused by the occupation of a large number of natural wetlands and the excessive coastal construction of cities and towns. Human activities in the coastal areas of northern Shandong decreased after 2010 due to the strengthening of control over the Yellow River Delta and surrounding areas after 2010 so as to reduce human activities and restore the natural landscape. The eastern coastal areas have been more affected by the opening-up policy than other areas and have thus attracted a number of industries, capital investments and migrants. Although the economy is developing rapidly, this development has increased the frequency with which land is developed and constructed. The Beijing–Tianjin–Hebei Urban Agglomeration is the largest socioeconomic area in China. North China, with this area at its core, has some of

the most impactful human activities (Figure 3), but the HAI in North China decreased in 2018 (Figure 2). Therefore, the Beijing–Tianjin–Hebei Urban Agglomeration adjusted its industrial structure and sought to transition transferred primary and secondary industries to tertiary industries. At the same time, measures such as setting up the Xiong'an New Area to relieve the pressure on the main urban area have achieved good results, reducing HAI and effectively controlling human activities.

At the national level, HAI in eastern China continues to increase, and changes in western China are slow to realize. The economic foundation of the eastern region is good, and development policies have favored this region. It has great advantages in terms of population inflow, resource allocation and social welfare. Therefore, the development and utilization of land are more urgent in coastal areas, where the ecosystem is becoming increasingly disturbed. When there is no urgent demand for land development in the western region, the HAI is low here, which makes the regional difference in HAI across China vary greatly. China's human activities are gradually showing a point-like "core" enhancement model, mainly concentrated in only a few provinces at the beginning of the research period. With changes in national policies and economic structure, each province has gradually seen certain cities experience rapid HAI growth. In terms of HAI decreases, the amount of the decrease has grown each year, indicating that in the early 1980s, China vigorously promoted the development of coastal or specific areas to ensure economic development and social construction, resulting in an increase in HAI in these areas. As China has achieved certain social development goals, the country began to shift the development direction toward balanced regional development. As part of ensuring development, China began to pay more attention to ecological balance, further reduce HAI, and effectively control human activities in some areas. However, there are still some challenges, such as the continuous growth of human activities, large differences between eastern and western China, the small radiation driving capacity of core cities in central and western China, the agglomeration of areas with high intensity of human activities, and the sustainable development of cities.

4.2. Influence Mechanism of Human Activity Intensity

Changes in human activities are the result of the complex coupling effect of many factors, such as geographical location and social development (Figure 7). Different historical backgrounds, development stages, national policies, industrial tendencies and other factors will affect changes in human activities. We explore the impact of seven factors, such as the economy, capital and industry, on human activities. We analyze the internal laws affecting HAI changes and make suggestions for improving human activities from the perspective of influencing factors [46].

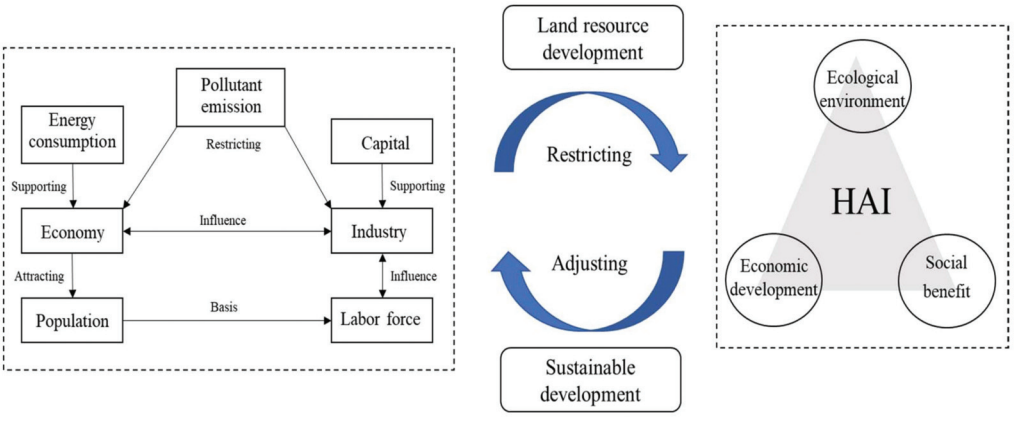


Figure 7. Influence mechanism of human activity intensity.

Economic and industrial levels are the main factors affecting human activities. Urban economic development means better treatment and supporting facilities to promote cities to attract foreign resources and population, while a high-quality labor force and excellent industrial resources will promote regional development and urbanization processes. Therefore, it is necessary to speed up land development and expand the scope of cities and towns to meet the needs of human production and life [47]. Industrial factors are the main factors affecting urban industrialization, which will not only increase the intensity of land development but also produce a series of problems, such as over-attracting foreign labor and migrants and increasing energy consumption and pollution [48,49]. Industrial enterprises and the labor force are the main factors supporting regional production, and capital is an important driving force for these enterprises. Quantity directly determines the demand for land development and urban construction. Although quantity plays an important role in promoting economic development and industrial rise, it also significantly enhances human interference with the surrounding environment and increases the radiation impact of human activities [50]. The impact of population on HAI is strong and stable. An excessive urban population will bring social problems such as residence and employment as well as place great pressure on the local ecological environment. At the same time, an excessive population will also have a negative impact on technological innovation [51], which is contrary to the goal of strengthening the construction of innovative industries. Therefore, the relationship among population, economy and human activities should be balanced. We should not only restrict population migration but also increase investment in education and improve the cultivation of scientific and technologically innovative talent. Before the country's industrial transformation, China's coal-based energy production and consumption mode was making the contradiction between the economy and ecological environment increasingly acute. After 2000, the decisive power of energy factors and pollution factors on human activities decreased significantly, indicating that China's regulation of energy consumption and pollutant emissions has since achieved certain results, but in the short term, the energy consumption structure has been difficult to change. Therefore, seeking effective ways to ensure reasonable energy consumption and pollution control is an important task in balancing HAI at this stage [52].

4.3. Enlightenment from Improving Human Activities

This paper explored and summarizes the temporal and spatial evolution of China's HAI. The year 1980 was one of the major turning points in China's economic development. The reform and opening-up policy led to rapid economic development and greatly accelerated the urbanization process, especially in the eastern region, where the changes were most obvious. Therefore, the negative impact of rapid economic development on the ecological environment is reflected through the intensity of human activities. Currently, China has made changes to address such issues. For example, Figure 4 shows the effectiveness of strengthening the development of the western interior, and the point distribution pattern of human activity intensity significantly indicates that China's development is gradually expanding outward from provincial capitals or large cities, enhancing the radiation drive and redistributing the pressure faced by the eastern regions. However, the country should also strengthen the management and control of human activities, restore and protect nature reserves and important wetlands, establish new economic development zones around major economic circles, adjust industrial structures, remove heavy pollution industries and develop innovative enterprises. Although the above measures have played a positive role in the trend of HAI in China, the overall effect has still been limited. At the same time, we cannot deny the role of human activities in promoting regional development. Controlling human activities is not done to limit regional development but to find effective ways to solve problems. To grasp the trend of human activities as a whole, in addition to continuing to strictly implement the existing measures, this study suggests the following measures: (1) China should integrate land resources, reasonably renovate and plan industrial bases, improve the resource utilization efficiency of old industrial bases in Northeast China, and

improve the intensive utilization of urban land [53]. (2) China should seek to establish a top-level scheme of land planning and ecological civilization, transfer industrial structures and disperse the focus of human activities. The eastern region has a good economic foundation. It should give full play to the dominant position of green innovation, vigorously develop high-tech industries [54], eliminate backward industries and strengthen the prevention and control of pollution emissions from industrial enterprises. (3) The central and western regions should rely on regional policies and attach importance to the dynamic role of private enterprises to adapt to the development strategy of the region, speed up the construction of a new development pattern [55], share the pressure of industrial transfer in eastern China, and build a national development active growth pole while ensuring ecological security. (4) China should focus on optimizing the industrial structure of small- and medium-sized cities, improving urban public services, enhancing the agglomeration capacity of small- and medium-sized cities, and promoting the balanced development of spatial layout and scale.

5. Conclusions

The excessive transformation of the Earth's surface caused by various human activities has a negative impact on the ecological environment, and it is urgently necessary to control human behaviors such as land development. The evaluation and attribution of HAI forms a basis for human activity regulation. The results of the study indicate that the HAI in China has increased from 15.27% to 20.60%, and there is a great variability between east and west. We found that in the beginning, the stronger the HAI the greater its increase was, even though HAI in Shandong and Beijing–Tianjin–Hebei region decreased after 2010.

By the approach of GDM, all the 7 influencing factors explored in this paper have significant impact on HAI. The economy is the main factor affecting human activities, followed by industrial, population, labor, and capital factors. In contrast, environmental pollution and energy consumption have little impact on human activities. In addition, HAI in China is the result of the mutual enhancement of multiple factors. The effects of the combined action of multiple factors on human activity are greater than the effect of a single factor. However, there are differences in the mutual enhancement between influencing factors in different periods. On the whole, the interaction coupling between the industrial factors and other factors has the most significant effect.

The HAI is impacted by multiple factors. Due to the difficulty in measuring or obtaining the data of some influencing indexes, this paper fails to fully detect the impact factors of HAI. Moreover, it is worth discussing that there are some limitations in using the GDM to explore the influencing factors. For example, the GDM can only reflect a factor or correlation among factors by q value, which will affect the exploration of HAI. Despite these limitations, we believe that this method is useful for improving human activity. In the future, we will enrich the influencing factors and research methods to reflect the influence mechanism of HAI in China or other countries.

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References

1. Sheng, J.; Zhou, W.; Zhang, S. The role of the intensity of environmental regulation and corruption in the employment of manufacturing enterprises: Evidence from China. *J. Clean. Prod.* **2019**, *219*, 244–257. [CrossRef]
2. Chen, Z.; Kahn, M.E.; Liu, Y.; Wang, Z. The consequences of spatially differentiated water pollution regulation in China. *J. Environ. Econ. Manag.* **2018**, *88*, 468–485. [CrossRef]
3. Han, R.; Feng, C.C.; Xu, N.; Guo, L. Spatial heterogeneous relationship between ecosystem services and human disturbances: A case study in Chuandong, China. *Sci. Total Environ.* **2020**, *721*, 137818. [CrossRef] [PubMed]
4. Zhou, D.Y.; Tian, Y.Y.; Jiang, G.H. Spatio-temporal investigation of the interactive relationship between urbanization and ecosystem services: Case study of the Jingjinji urban agglomeration, China. *Ecol. Indic.* **2018**, *95*, 152–164. [CrossRef]
5. Huang, J.P.; Zhang, G.L.; Zhang, Y.T.; Guan, X.D.; Wei, Y.; Guo, R.X. Global desertification vulnerability to climate change and human activities. *Land Degrad. Dev.* **2020**, *31*, 1380–1391. [CrossRef]
6. Venter, O.; Sanderson, E.W.; Magrach, A.; Allan, J.R.; Beher, J.; Jones, K.R.; Possingham, H.P.; Laurance, W.F.; Wood, P.; Fekete, B.M. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nat. Commun.* **2016**, *7*, 12558. [CrossRef]
7. Holden, E.; Linnerud, K.; Banister, D. The Imperatives of Sustainable Development. *Sustain. Dev.* **2017**, *25*, 213–226. [CrossRef]
8. Wang, H.Y.; Li, B.Z. Environmental regulations, capacity utilization, and high-quality development of manufacturing: An analysis based on Chinese provincial panel data. *Sci. Rep.* **2021**, *11*. [CrossRef]
9. Marsh, G.P. *Man and Nature, Physical Geography as Modified by Human Action*; Charles Scribner: New York, NY, USA, 1865.
10. Dey, P.; Mishra, A. Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions. *J. Hydrol.* **2017**, *548*, 278–290. [CrossRef]
11. Zheng, K.; Wei, J.Z.; Pei, J.Y.; Cheng, H.; Zhang, X.L.; Huang, F.Q.; Li, F.M.; Ye, J.S. Impacts of climate change and human activities on grassland vegetation variation in the Chinese Loess Plateau. *Sci. Total Environ.* **2019**, *660*, 236–244. [CrossRef]
12. Hannah, L.; Lohse, D.; Hutchinson, C.; Carr, J.L.; Lankerani, A. A preliminary inventory of human disturbance of world ecosystems. *Ambio* **1994**, 246–250. [CrossRef]
13. Chen, H.; Zhu, Q.; Peng, C.; Wu, N.; Wang, Y.; Fang, X.; Gao, Y.; Zhu, D.; Yang, G.; Tian, J. The impacts of climate change and human activities on biogeochemical cycles on the Qinghai-Tibetan Plateau. *Glob. Change Biol.* **2013**, *19*, 2940–2955. [CrossRef] [PubMed]
14. Zhang, G.Q.; Yao, T.D.; Chen, W.F.; Zheng, G.X.; Shum, C.K.; Yang, K.; Piao, S.L.; Sheng, Y.W.; Yi, S.; Li, J.L.; et al. Regional differences of lake evolution across China during 1960s–2015 and its natural and anthropogenic causes. *Remote Sens. Environ.* **2019**, *221*, 386–404. [CrossRef]
15. Magalhães, J.L.L.; Lopes, M.A.; de Queiroz, H.L. Development of a Flooded Forest Anthropization Index (FFAI) applied to Amazonian areas under pressure from different human activities. *Ecol. Indic.* **2015**, *48*, 440–447. [CrossRef]
16. Roth, D.; Moreno-Sanchez, R.; Torres-Rojo, J.M.; Moreno-Sanchez, F. Estimation of human induced disturbance of the environment associated with 2002, 2008 and 2013 land use/cover patterns in Mexico. *Appl. Geogr.* **2016**, *66*, 22–34. [CrossRef]
17. Xu, X.; Xu, Y. Analysis of spatial-temporal variation of human activity intensity in Loess Plateau region. *Geogr. Res.* **2017**, *36*, 661–672. [CrossRef]
18. Xu, Y.; Xu, X.; Tang, Q. Human activity intensity of land surface: Concept, methods and application in China. *J. Geogr. Sci.* **2016**, *26*, 1349–1361. [CrossRef]
19. Jiang, C.; Xiong, L.; Wang, D.; Liu, P.; Guo, S.; Xu, C.-Y. Separating the impacts of climate change and human activities on runoff using the Budyko-type equations with time-varying parameters. *J. Hydrol.* **2015**, *522*, 326–338. [CrossRef]
20. Sun, Y.; Liu, S.; Shi, F.; An, Y.; Li, M.; Liu, Y. Spatio-temporal variations and coupling of human activity intensity and ecosystem services based on the four-quadrant model on the Qinghai-Tibet Plateau. *Sci. Total Environ.* **2020**, *743*, 140721. [CrossRef]
21. Zhang, X.; Xu, Z. Functional coupling degree and human activity intensity of production–living–ecological space in underdeveloped regions in China: Case study of Guizhou Province. *Land* **2021**, *10*, 56. [CrossRef]
22. Chen, Z.; Yu, B.; Ta, N.; Shi, K.; Yang, C.; Wang, C.; Zhao, X.; Deng, S.; Wu, J. Delineating seasonal relationships between Suomi NPP-VIIRS nighttime light and human activity across Shanghai, China. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2019**, *12*, 4275–4283. [CrossRef]
23. Duraiappah, A.K. Ecosystem services and human well-being: Do global findings make any sense? *BioScience* **2011**, *61*, 7–8. [CrossRef]
24. Lang, Y.; Zhiyuan, R.; Chong, Z.; Wen, L. Vegetation cover, climate and human activities on the Loess Plateau. *Resour. Sci.* **2014**, *36*, 166–174.
25. Ye, X.; Zhang, Q.; Liu, J.; Li, X.; Xu, C.-y. Distinguishing the relative impacts of climate change and human activities on variation of streamflow in the Poyang Lake catchment, China. *J. Hydrol.* **2013**, *494*, 83–95. [CrossRef]
26. Ding, Y.; Zhang, M.; Qian, X.; Li, C.; Chen, S.; Wang, W. Using the geographical detector technique to explore the impact of socioeconomic factors on PM2. 5 concentrations in China. *J. Clean. Prod.* **2019**, *211*, 1480–1490. [CrossRef]
27. Ju, H.; Zhang, Z.; Zuo, L.; Wang, J.; Zhang, S.; Wang, X.; Zhao, X. Driving forces and their interactions of built-up land expansion based on the geographical detector–a case study of Beijing, China. *Int. J. Geogr. Inf. Sci.* **2016**, *30*, 2188–2207. [CrossRef]

28. Dong, S.; Pan, Y.; Guo, H.; Gao, B.; Li, M. Identifying Influencing Factors of Agricultural Soil Heavy Metals Using a Geographical Detector: A Case Study in Shunyi District, China. *Land* **2021**, *10*, 1010. [CrossRef]
29. Hu, Y.; Xia, C.; Li, S.; Ward, M.P.; Luo, C.; Gao, F.; Wang, Q.; Zhang, S.; Zhang, Z. Assessing environmental factors associated with regional schistosomiasis prevalence in Anhui Province, Peoples' Republic of China using a geographical detector method. *Infect. Dis. Poverty* **2017**, *6*, 1–8. [CrossRef]
30. Balland, P.-A.; Jara-Figueroa, C.; Petralia, S.G.; Steijn, M.P.; Rigby, D.L.; Hidalgo, C.A. Complex economic activities concentrate in large cities. *Nat. Hum. Behav.* **2020**, *4*, 248–254. [CrossRef]
31. Liu, C.; Zhang, H.; Li, Q. Spatiotemporal characteristics of human activity intensity and its driving mechanism in Hainan Island from 1980 to 2018. *Prog. Geogr.* **2020**, *39*, 567–576. [CrossRef]
32. Li, J.; Liu, Y.; Yang, Y.; Liu, J. Spatial-temporal characteristics and driving factors of urban construction land in Beijing-Tianjin-Hebei region during 1985–2015. *Geogr. Res.* **2018**, *37*, 37–52. [CrossRef]
33. Li, Y. Research on the Measurement and Spatial Characteristics of China's Provincial R&D Capital Stock. *Soft Sci.* **2019**, *33*, 21–26. [CrossRef]
34. Wu, Y. The role of productivity in China's growth: New estimates. *J. Chin. Econ. Bus. Stud.* **2008**, *6*, 141–156. [CrossRef]
35. Chuai, X.; Huang, X.; Qi, X.; Li, J.; Zuo, T.; Lu, Q.; Li, J.; Wu, C.; Zhao, R. A preliminary study of the carbon emissions reduction effects of land use control. *Sci. Rep.* **2016**, *6*, 1–8. [CrossRef]
36. Peng, K.; Zhang, Y.; Gao, W.; Lu, Z. Evaluation of human activity intensity in geological environment problems of Ji'nan City. *Eur. J. Remote Sens.* **2021**, *54*, 117–121. [CrossRef]
37. Galton, F. Regression towards mediocrity in hereditary stature. *J. Anthropol. Inst. Great Br. Irel.* **1886**, *15*, 246–263. [CrossRef]
38. He, Y.; Chen, Y.; Tang, H.; Yao, Y.; Yang, P.; Chen, Z. Exploring spatial change and gravity center movement for ecosystem services value using a spatially explicit ecosystem services value index and gravity model. *Environ. Monit. Assess.* **2011**, *175*, 563–571. [CrossRef]
39. Shi, Y.; Matsunaga, T.; Yamaguchi, Y.; Li, Z.; Gu, X.; Chen, X. Long-term trends and spatial patterns of satellite-retrieved PM2. 5 concentrations in South and Southeast Asia from 1999 to 2014. *Sci. Total Environ.* **2018**, *615*, 177–186. [CrossRef]
40. Wang, J.; Xu, C. Geodetector: Principle and prospective. *Acta Geogr. Sin.* **2017**, *72*, 116–134. [CrossRef]
41. Wang, J.F.; Hu, Y. Environmental health risk detection with GeogDetector. *Environ. Modell. Softw.* **2012**, *33*, 114–115. [CrossRef]
42. Han, M.; Zhang, C.; Lu, G.; Liu, Y.; Yu, H. Response of wetland landscape pattern gradient to human activity intensity in Yellow River Delta. *Trans. Chin. Soc. Agric. Eng.* **2017**, *33*, 265–274. [CrossRef]
43. Li, J.; Zhang, Y.; Wang, X.; Qin, Q.; Wei, Z.; Li, J. Application of GPS trajectory data for investigating the interaction between human activity and landscape pattern: A case study of the Lijiang River Basin, China. *ISPRS Int. J. Geo-Inf.* **2016**, *5*, 104. [CrossRef]
44. Zheng, J.; Chen, G.; Zhang, T.; Ding, M.; Liu, B.; Wang, H. Exploring Spatial Variations in the Relationships between Landscape Functions and Human Activities in Suburban Rural Communities: A Case Study in Jiangning District, China. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9782. [CrossRef] [PubMed]
45. Niu, B.; Ge, D.; Yan, R.; Ma, Y.; Sun, D.; Lu, M.; Lu, Y. The evolution of the interactive relationship between urbanization and land-use transition: A case study of the Yangtze River Delta. *Land* **2021**, *10*, 804. [CrossRef]
46. Wu, R.N.; Zhang, J.Q.; Bao, Y.H.; Zhang, F. Geographical Detector Model for Influencing Factors of Industrial Sector Carbon Dioxide Emissions in Inner Mongolia, China. *Sustainability* **2016**, *8*, 149. [CrossRef]
47. Liu, Y.; Zhang, X.; Kong, X.; Wang, R.; Chen, L. Identifying the relationship between urban land expansion and human activities in the Yangtze River Economic Belt, China. *Appl. Geogr.* **2018**, *94*, 163–177. [CrossRef]
48. Fu, Y.; Gabriel, S.A. Labor migration, human capital agglomeration and regional development in China. *Reg. Sci. Urban Econ.* **2012**, *42*, 473–484. [CrossRef]
49. Zeng, X.; Xiang, H.; Xue, Y.; Su, Y.; Tong, Y.; Mao, Z. A scenario-based optimization frame to adjust current strategy for population-economy-resource-environment harmony in an urban agglomeration, China. *Sustain. Cities Soc.* **2021**, *67*, 102710. [CrossRef]
50. Prenzel, P.; Iammarino, S. Labor Force Aging and the Composition of Regional Human Capital. *Econ. Geogr.* **2021**, *97*, 140–163. [CrossRef]
51. Suzuki, K.; Ha, H.; Avellaneda, C.N. Direct and non-linear innovation effects of demographic shifts. *Aust. J. Public Adm.* **2020**, *79*, 351–369. [CrossRef]
52. Managi, S. Are there increasing returns to pollution abatement? Empirical analytics of the Environmental Kuznets Curve in pesticides. *Ecol. Econ.* **2006**, *58*, 617–636. [CrossRef]
53. Hui, E.C.; Wu, Y.; Deng, L.; Zheng, B. Analysis on coupling relationship of urban scale and intensive use of land in China. *Cities* **2015**, *42*, 63–69. [CrossRef]
54. Harrison, R.; Jaumandreu, J.; Mairesse, J.; Peters, B. Does innovation stimulate employment? A firm-level analysis using comparable micro-data from four European countries. *Int. J. Ind. Organ.* **2014**, *35*, 29–43. [CrossRef]
55. Du, J.; Mickiewicz, T. Subsidies, rent seeking and performance: Being young, small or private in China. *J. Bus. Ventur.* **2016**, *31*, 22–38. [CrossRef]

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Economic Drivers of Voluntary Return among Conflict-Induced Internally Displaced Persons in Nigeria

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Abstract: North-East Nigeria is recovering from a decade of terrorism by Boko Haram during which the region collapsed socioeconomically and millions were displaced. The displaced live in various camps in Adamawa, Borno, and Yobe States, and serve as the primary source of data for this research. The Nigerian government has expressed their desire for the displaced to return home following peace restoration to the region. Their unwillingness to return despite the perceived gains of reintegration prompted this research to examine economic determinants of willingness for reintegration. Logistics regression results show a strong positive influence of having an assurance of finding employment back home on the willingness for reintegration. The results further suggest that displaced persons are 14 times more willing to return home when the government guarantees employment. To encourage willingness for reintegration, the authors recommend that displaced persons be empowered economically through the provision of jobs upon their return to their various home communities. Recommendations for the Nigerian government and interested parties are presented with suggestions to expand social institutions and their collaboration with the government.

Keywords: displaced persons; socioeconomics; government; return; unwillingness; reintegration; Boko Haram; North-East Nigeria

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1. Introduction

One of the causes of population displacement is terrorism; it has become a global phenomenon in recent times. This is especially so in countries such as Afghanistan, Iraq, Syria, Pakistan, and Yemen in the Middle East and Nigeria, Somalia, Niger, Chad, D.R. Congo, Burkina Faso, Sudan, and Libya in Africa—all of which are ranked among the 20 most terrorized countries in the 2020 Global Terrorism Index [1]. Besides terrorism casualties, which is estimated in the millions, 82.4 million people were displaced in 2020, with 48 million of them remaining within their country of origin. People displaced within their countries are called internally displaced persons (IDPs), most of who live in makeshift camps within countries where they were displaced [2]. In Nigeria, Boko Haram has killed over 20,000 people, and over 2.5 million have been displaced since 2009 [1–3]. According to the Principle 28 of the United Nations Guiding Principles on IDPs, the government of each nation with IDPs, should collaborate with relevant humanitarian agencies to coordinate camps, provision relief materials, and develop skills acquisition [4]. To promote sustainable reintegration, the United Nations High Commission for Refugees funds basic needs and livelihood projects [5] which include community empowerment programs [6], microcredit,

and cooperation-based schemes used to link IPDs to formal financial services [7]. Successful reintegration of IDPs depends on the implementation and monitoring of agreed principles at the local, regional, and national level [8]. The government in partnership with these agencies also coordinate IDPs reintegration efforts after the restoration of peace. The Nigerian government has played a leading role in IDP reintegration, through the National Commission for Refugees, Migrants, and Internally Displaced Persons, and the National and State Emergency Management Agencies (NEMA and SEMA) in partnership with international organizations such as the United Nations High Commission for Refugees, International Organization for Migration (IOM), and International Red Cross. As such, there are several IDPs camps in North-East Nigeria erected by the Federal government through NEMA in partnership with state governments and SEMA [9–11]. There are also more makeshift camps built by IOM and the United Nations Children's Fund (UNICEF) in North-East Nigeria [9,12]. Moreover, the government established the North-East Development Commission in 2016 to oversee possible sustainable mechanisms for reintegrating its IDPs [13].

Terrorism has crippled the socioeconomic development of North-East Nigeria, i.e., the operation base of Boko Haram. Many villages have been destroyed, and economic activities were destabilized through the destruction of markets, banking halls, and farmlands. Consequently, livelihoods in these geopolitical areas are extremely difficult. Due to increased counterterrorism through the joint military task force among Nigeria, Niger, Chad, and Cameroon, North-East Nigeria has experienced relative peace since 2017, except for a slight relapse in the first quarter of 2019. As a result, some IDPs have voluntarily returned to their communities of origin (COO) while some still reside in host communities across North-East Nigeria. The Nigerian government has persuaded them to return home in the wake of relative peace in their COO to start life afresh and earn a living. However, most of the IDPs are still unwilling to return, a decision attributed to the destruction of their villages and means of economic survival during the peak of terrorism in the region (i.e., between 2014 and 2016). Even though it is important that the IDPs return, reintegration must be voluntary because enforced reintegration or repatriation is against international refugee law as enshrined in the United Nations Guiding Principles on IDPs [4,14]. Nonetheless, it is still the government's desire for IDPs to return to their COO to overcome social, security, and economic barriers, and aid in rebuilding a more united, prosperous country. For instance, situations of violation against the rights of IDPs have been traced to as far back as the Second World War [15,16] and, unfortunately, have not abated, especially in Africa and in the Middle East. The lack of or inadequate finance has also been one of the main challenges of IDPs in Nigeria and other African countries such as D.R. Congo, Rwanda, Liberia, Sierra Leone, and Mozambique—since most are unemployed [17–19]. As a result, the need to return home or integrate elsewhere to be able to earn a living is prioritized and remains critical to the country's development. As such, it is necessary to investigate reasons why IDPs in Nigeria show apathy towards reintegration despite peace restoration in their COO.

Kveder and Flahaux [20] found a positive relationship between displacement and capital accumulation among forced migrants, especially those who found better-paying jobs or crossed international borders. Their unwillingness to return when the government makes a call for reintegration is closely documented. Successful reintegration goes beyond economic reintegration to include social and political reintegration with IDPs full participation in their communities and political landscape [21]. In the Philippines, IDPs' top three considerations for return was reported on by Collado [22], i.e., (1) employment opportunities, (2) available business capital assistance, and (3) financial assistance for housing. Moreover, another recent study found that although peace restoration is welcomed, unless sources of water both for domestic and agrarian purposes are available, most of which were damaged in the peak of the insurgency in North-East Nigeria are restored, displaced persons would not be willing to return to their COO [19,23]. More so, the return of displaced persons to their former communities has induced several disputes on repossession of real estate property in some African countries with weak relevant social institutions unable to find plausible

solutions. The fear of escalation of post-return riots on repossession of real estate properties might also make Nigerian IDPs unwilling to return. For IDPs in Burundi, asset ownership such as land and livestock upon reintegration and community support correlated with a desire to return and cope with food security [24]. Moreover, access to improved healthcare across IDPs camps and host communities among elderly and reproductive IDP women are also key reasons some displaced persons in Turkey and Afghanistan were reluctant to return to their COO [25,26]. A recent study also associated reluctance to voluntary return with power outage in those communities that had electricity before displacement [23]. Some studies also found that the reluctance of ex-warlords, child soldiers, and combatants to return home is based on the difficulty to gain acceptance, warmth, and love back from their communities at the expiration of war, e.g., Uganda, Sierra Leone, and Liberia [18,27]. This, however, is not the case in Nigeria because Nigerian IDPs are not ex-soldiers or warlords. Reintegration to post-conflict communities has been found not only a boost in socioeconomic activities but also has been linked with induced urbanization [19,28] and school resumption for displaced school aged children. This is crucial since Catalano [29] conferred that unless concerted efforts are made by parents, and backed by a strong institutional framework, the effects of forced displacement on primary school pupils may be long-lasting.

Despite these perceived and real benefits of reintegration, IDPs in Nigeria are still showing apathy to it. There is a dearth in the literature on IDPs' reluctance to return home and why in Nigeria the case is no different. Employing Cernea's [30] Risk, Safeguard, and Reconstruction Model, this research, in retrospect, examines the core economic drivers of willingness for voluntary return among conflict-induced internally displaced persons (CiIDPs) in North-East Nigeria. The findings from the study will contribute to the existing literature on social factors found in previous studies [19,25,26,31]. Findings will also help the Nigerian government decide which economic factors are pertinent to encourage reintegration among IDPs in Nigeria. Moreover, it will help stakeholders and policymakers build social institutions and agencies to drive the demands of displaced persons towards sustainable development in COO. This will help to solve the problem of poverty and hunger among CiIDPs in Nigeria, which interrelates with the United Nations Sustainable Development Goals (SDGs)—specifically, SDG1 and SDG2.

2. Risks, Safeguard, and Reconstruction Model: Population Displacement and Resettlement

This research uses Cernea's [30] Risk, Safeguard, and Reconstruction Model which is one of the foremost models proposed in the early 1980s for guiding equity during population displacement and resettlement programs. In this model, Cernea [30] identified a high level of inequality and injustice by displaced persons especially during reconstruction and development. This is important since IDPs can share the benefits of growth economically, socially, and—in a community sense—emotionally. According to Cernea [30], resettlement must be socially responsible, guided by equity so that no returning CiIDP is impoverished after resettlement. To deal with any form of impoverishment, it is suggested that a risk and reconstruction framework for resettlement operations is structured; it will need to be framed in such a way that the unintended flaws associated with policies and methodologies of planning and financing resettlement projects is closely considered and appropriately administered.

Cernea [30] argues that before resettlement, displaced persons need rehabilitation to address the trauma they have experienced. In most cases, however, this does not happen. For example, during the intensive reconstruction project in India in the early 1990s, 75% of those displaced were not rehabilitated and were more impoverished than prior to their displacement [32–34]. This is not limited to India, as such impoverishments and injustices are endemic in developing countries [15,27,35]. Furthermore, the social exclusion that displaced persons suffer [36,37] which is contrary to the true intention of resettlement and development. Worried by these trends, i.e., those associated with reconstruction and

development, Cernea [30] developed a model of risks and risk avoidance anchored on four intrinsic concepts. The first concept suggests that wherever resettlement is to take place, the landless, homeless, and jobless must be protected and provided with economic recovery routes. Second, marginalization must be discouraged at every stage of the reconstruction and resettlement processes. Third, there must be a focus on food security to ensure sustenance during displacement. Fourth, the restoration of land and other resources to the rightful owners must be employed [30]. Together, these four concepts will facilitate that the reconstruction and development processes are just, equitable, and fair. On the other hand, if they are not fulfilled, the displaced will either be reluctant to return or be impoverished at the end of the integration process.

3. Materials and Methods

A structured questionnaire served as the primary instrument of data collection for this study. The questionnaire contains two sections. Section A examines the background characteristics of the respondents, while section B made inquiries into the economic determinants of willingness for voluntary return among CiIDPs in Nigeria. A total of 928 respondents were randomly selected from CiIDPs in selected IDPs camps across the three core states in North-East Nigeria, i.e., where Boko Haram activities were intense, leading to unprecedented displacements. A list of all IOM recognized IDPs camps in three of Nigeria's states are presented in Table 1. After the listing and number of IDPs were recorded, systematic sampling was performed and two IDPs camps in Adamawa State, two in Yobe State, and four in Borno State were assayed. Furthermore, four camps were selected in Borno State since it housed over 70% of all the IDPs in Nigeria. Having synthesized the statistics, systematic sampling method was used to select the first and third camp in Adamawa State, the first, fourth, seventh, and tenth camp in Borno State, being the state with the largest number of IDP camps, and the first and third camp in Yobe State. This implied that eight IDPs camps were systematically selected for sampling. The total number of questionnaires that were administered in each IDPs camp was proportionally calculated according to the number of IDPs in each camp so as to deal with the issue of skewness. It is important to state that many of the IDPs camps have closed because many IDPs have settled down in host communities which are relatively peaceful. However, the listed camps and the number of IDPs in each are still recognized by the Federal government as well as the states where they are cited. The total number of IDPs remaining in camps across the North-East is 34,110 IDPs, which was benchmarked as the target population for the study. When the target population (i.e., 34,110 IDPs) is divided by the sample size of 928, it gives a score of 36.8. This infers that approximately, one IDP per 37 IDPs in North-East was interviewed for the study, making it a representative sample of IDPs with similar challenges.

Respondents were asked to select from a range of questions specific to economic need and what might likely induce their willingness to voluntarily return home, as well as what might make the return sustainable. Their responses were later regrouped and recoded into four categories: 1–3, 4–6, 7–9, and 10–12 which connote economic needs that are "not a priority, low, high, and highest priority", respectively, to their willingness for voluntary return. The four economic needs that were ranked by the respondents are reintegration and financial assistance (RFA), subsidized agricultural implements and seed stock (SAIS), employment and job opportunities (EJO), and opening of commercial centers (OCC). It is important to note that SAIS refers to the common crops such as improved maize seed, millet, sorghum, beans, and improved rice seed stock which were grown in the environment prior to the displacement as well as subsidized amount for hiring tractors, mowers, and other heavy equipment for mechanized agriculture. These core economic needs emanate from extensive review of similar literature [27,38,40–43] on economic factors that encouraged displaced persons to return home after peace restoration to their communities in Liberia and Uganda. Since the IDPs were displaced from agrarian communities, most of them were farmers prior to being displaced. The idea behind the grouping was to examine which economic needs innovatively and intuitively would induce the interest of CiIDPs in Nigeria

to return home. The displaced were also asked to list any other economic needs which may encourage them to a voluntary return. The study sought this additional information for three scientific reasons. One, it wanted new contributions to knowledge going beyond what previous base knowledge explored. Two, the background characteristics of IDPs in Nigeria might be different from those in Liberia and Uganda, i.e., country-specific requisites. Third, the environment (i.e., microclimate) in Nigeria is different from Liberia and Uganda, and such a factor may play a part in IDPs' decision to return to their COO.

Table 1. Names of camps and numbers of IDPs in North-East, Nigeria, dated 28 February 2018.

S/N	Locations of IDPs Camps	Estimated Population of IDPs in Camp
	IDPs camps in Adamina State	
1	Damare Camp, Fufore LGA	1845
2	Angwan Kara Camp, Girei LGA	784
3	Malkohi Camp, Yola South LGA	1491
	Total Number of IDPs in Adamawa State	4120
	IDPs camps in Borno State	
1	NYSC Camp Maiduguri	5587
2	Chad Basin Camp, Bornu State	5336
3	Government Girls' College, Maiduguri	4750
4	Dalori I & II IDPs Camp	7500
5	Government Girls' Secondary School, Yelwa	5681
6	Government Girls' Secondary School, Biu	2250
7	Bakasi/Farm Centre IDPs Camp	6000
8	Government Secondary School, Maiduguri	3352
9	Wulari IDP Camp, Maiduguri	9021
10	Shetima Ali Monguno IDPs Camp	2000
11	Sanda Kyarimi Secondary School	1003
12	Ngomari Gana Primary School	2700
	Total Number of IDPs in Borno State	55,180
	IDPs camps in Yobe State	
1	Sabonsara IDPs Camp, Potiskum LGA	651
2	Pompomari Primary School Camp, Gubja LGA	1850
3	YBC Camp, Damaturu LGA	9036
	Estimated Total Number of IDPs in Yobe State	11,536
	Estimated Grand total for Adamawa, Borno, Yobe States	70,837

Source: IOM [38] and Enitan-Matthews [39] as supplied by NEMA.

The study's ethical issues on investigating human subjects were in-line with Covenant University Health Research Ethics Committee and international best practices were adopted according to the Helsinki Declaration. Participants gave their informed consent and received information about the nature of the study, about the voluntary nature of their participation, and that they could withdraw at any stage of the discussion if they felt unsafe or unsatisfied with the questions asked. The researchers also assured participant anonymity and privacy. In terms of the validity and reliability of the research data, similar studies of this nature in Africa, Asia, and Latin America [18,38,40,44–48] have used the same method and recorded bountiful results. Scientifically, the reliability of data of this nature is cross validated if similar results have been obtained in similar research endeavors. Except for gender distribution of the respondents, most other results obtained in this research, especially on security, capital for business, and skill acquisition validate findings from other similar studies. Data collection lasted for 5 months. This study used two levels of data analysis: univariate and multivariate. The univariate technique was adopted to analyze the background characteristics of the respondents while for the multivariate level, binary logistic regression was employed to estimate the odds of willingness for voluntary return—controlling for respondent-selected socioeconomic needs. Binary logistics was

adopted because the response to the dependent variable (i.e., willingness to return) is dichotomous, categorical, and cannot be ordered. Willingness to return was responded to as 'unwilling' (i.e., 0) and 'willing' (i.e., 1). The description of the regression model adopted for this study used Equation (1).

$$\text{Log p/1-P} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots \; B_n X_n + e \quad (1)$$

where: P is the likelihood of willingness to return based on the selected economic needs, 1-P is the likelihood of unwillingness to return given the same selected economic needs; X_1, $\dots$ X_n are a set of independent variables earlier stated; α is the regression constant; B_n are regression coefficients; and e is the error term.

The implicit function of the model is stated as Equation (2).

$$\text{Y} = \text{f(X, T)} \quad (2)$$

where: Y is the willingness to return (i.e., dependent variable); X is the vector for background characteristics denoted as follows: SOO—State of Origin, RC—Residence Category, E—Ethnicity, LE—Level of Education, A—Age, and DC—Duration in the Camp; and T is the vector for economic variables denoted as follows: RFAS, SAIS, EJO, and OCC.

The explicit function of the model is stated, thus, using Equation (3).

$$\text{Y} = \beta + \beta_1 \text{RFA} + \beta_2 \text{E} + \beta_3 \text{AIS} + \beta_4 \text{OCC} + \dots \; e \quad (3)$$

where: Y is the dependent variable representing willingness to return; β_1 to β_4 are the regression coefficient; and e is the error term.

4. Results

4.1. Background Characteristics of Respondents

At the end of the fieldwork, 866 questionnaires were found eligible for the study, which gives a response rate of 93.3%. The descriptive analysis of selected background characteristics of the respondents is shown in Table 2. The majority (i.e., 73.6%) of the displaced persons in Nigeria were from Borno State while 21.9% and 4.5% were from Yobe and Adamawa States, respectively. Inquiry into their residence categories before displacement shows that most (i.e., 71.8%) of the displaced persons were actually from rural communities, while 15.2% were displaced from semi-urban communities, and about 13% were displaced from urban centers. As for age categories, the results showed that 19.9% of the displaced ranged between 15 and 24 years old, 38.5% were between 25 and 34 years old, 25.4% were between 34 and 44 years old, 11.3% were between 45 and 54 years old, and 5% were 55 years and above.

Table 2. Selected background characteristics of the respondents.

Selected Socio-Demographic Characteristics	Frequency	Percentage
State of origin		
Borno State	637	73.6
Adamawa State	39	4.5
Yobe State	190	21.9
Residence prior displacement		
Rural	622	71.8
Semi-urban	132	15.2
Urban	112	12.9
Age		
15–24	172	19.9
25–34	333	38.5
35–44	220	25.4
45–54	98	11.3
55 and above	43	5.0

Table 2. *Cont.*

Selected Socio-Demographic Characteristics	Frequency	Percentage
Sex		
Female	263	30.4
Male	603	69.6
Level of education		
No formal education	564	65.1
Primary education	145	16.7
Nomadic primary education	26	3.0
Secondary education	105	12.1
Tertiary education	26	3.0
Marital status		
Single	133	15.4
Married	618	71.4
Divorced	36	4.2
Widowed	64	7.4
Never married	15	1.7
Duration in the camp		
1 Year	32	3.7
2 Years	175	20.2
3 Years	362	41.8
4 Years and above	297	34.3
Occupation prior displacement		
Farming	479	55.3%
Trade and business	115	13.3
Civil servant	73	8.4
Artisan	69	8.0
Self-employed and other	130	14.0
Income level prior displacement		
Below NGN 20,000	362	41.8
NGN 20,000–NGN 39,999	224	25.9
NGN 40,000–NGN 59,999	82	9.5
NGN 60,000–NGN 79,999	100	11.5
NGN 80,000 and above	18	2.1
Not applicable	80	9.2

Source: Authors' own compilation from the field survey, 2021.

Surprisingly, results about gender distribution of CiIDPs in North-East Nigerian camps showed that 30.4% of the displaced persons are female, while 69.6% of them are male. It should be noted that one of the reasons for this gender distribution was children less than 15 years old were left out of the study since they might not be able to account for economic variables that induce return willingness. Results about their educational status showed that more than half (i.e., 65.1%) of them did not have formal education. Those who have primary education were 16.7%, while 3%, 12.1% and 3% have nomadic primary education, secondary education, and tertiary education, respectively. Inquiry about their occupation before displacement showed that above half (i.e., 55.3%) of them were farmers while only 8.4% were civil servants. Those who were into businesses before being displaced were 13.3% while 8% were artisans. In addition, 4.7% were self-employed and others and those who ticked not applicable most likely were not working in any capacity (i.e., 1.8%). The result on marital status shows that 15.4% of the displaced persons in Nigeria who participated in the study were single while 71.4% were married; 4.2% of the displaced were divorced, and 7.4% and about 2% were widowed and never married, respectively. These never-married IDPs are those who have one or two births out of wedlock and those cohabiting. Income level of the respondents prior displacement was also examined, indicating that almost 49% of the Nigerian IDPs earned less than NGN 20,000 per month (i.e., USD 48) before being displaced. Distribution of other categories of earnings shows that about 30% of them earned between NGN 20, 000 and NGN 39,999 (i.e., USD 49 and USD 98) while 9.5% and 11.5% earned between NGN 40,000–59,999 (i.e., USD 99–148) and NGN 60,000–79,999

(i.e., USD 149–198), respectively. Only 2.1% of the IDPs in Nigeria earned NGN 80,000 (i.e., USD 199) or above per month before displacement. Those who were not working (i.e., 9.2%) before displacement said this variable did not apply to them. Finally, an inquiry into duration spent so far in camp showed that 3.7% of them had spent 1 year in the camp and 20.2% had spent 2 years in the camp. About 42% of them had spent 3 years, while 34.3% had spent 4 years and above in the camp.

4.2. Economic Needs of CiIDPs and Willingness for Voluntary Return

To reiterate the scaling of the economic needs, the rank of "not a priority" meant that displaced persons did not need such requirements for them to willingly return. For those ranked as "low priority," it meant that although the displaced persons needed them, they were not too important to the community and they could live without for some time. While the rank of "high priority" meant the requirement was very important and such a need would affect their level of sustenance and survival. Finally, those ranked as the "highest priority" were those that the displaced would not even contemplate returning unless they were available. These four economic needs of reintegration of financial assistance is IOM benchmarked at a minimum of USD 580 for every returnee in an ideal situation [38]. The other three economic needs are EJO in the post-conflict communities, SAIS being an agrarian society, and OCC such as banks, shopping malls, local markets, and the like.

RFA, otherwise popularly referred to as reparation, meant a little amount of money given to migrants when they are returning to their COO after displacement for a certain period. The money is intended to help them settle quickly, feed themselves for a short period, or establish themselves in micro-businesses to discourage begging—especially in the first few months of return. The results of their ranking are presented in Figure 1. RFA for the initial stability on return ranks the highest (i.e., 89.4%) among the displaced persons for willingness to return, and only 3.1% as not a priority. Besides ranking as the highest priority, 6.9% also ranked it as high priority to their willingness for voluntary return. This implies that cumulatively, 96.3% of the IDPs in Nigeria ranked RFA as the most crucial demand for willingness for a voluntary to return to their COO.

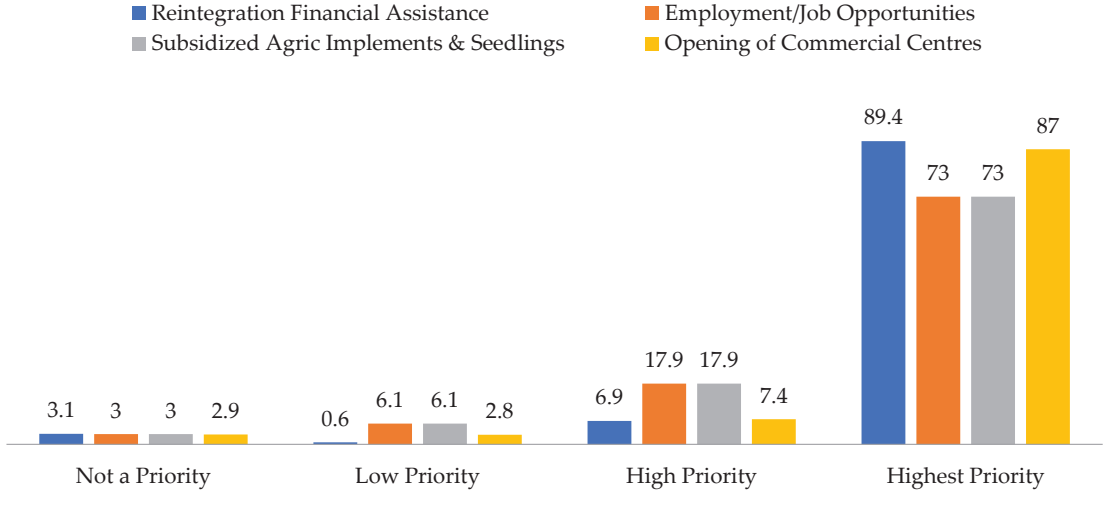


Figure 1. Economic needs towards willingness for voluntary return of CiIDPs, percentage.

EJO had a rank of 73% for the highest priority while 3% said it was not a priority. If combined with 17.9% who said EJO was of high priority, it implies that cumulatively 90.9% of them ranked EJO as of significant priority to their willingness for voluntary return. Moreover, 73% of them said that SAIS such as tractors, fertilizer, and high-yield seed stock

were of highest priority to them while 3% said they were not a priority. Lastly, only 2.9% of the respondents said that OCC such as markets, shopping complex, stores, and other such services were not a priority to their willingness for voluntary return, as 87% said that was of the highest priority. If combined with 7.4% who ranked OCC as a high priority, it implies that 94.4% of the displaced persons in Nigeria see OCC as very crucial to their willingness for voluntary return. This places OCC as the second-best ranked economic variable besides RFA.

4.3. Other Suggested Economic Drivers of Voluntary Return among CiIDPs

Respondents were given the opportunity to list additional economic needs which they desired but were not part of the ranking. The research identified this type of exploration as a first of its kind within the literature on reintegration, and the responses were most revealing. The results of the list are presented in Figure 2. It showed that capital for business topped the list of the needs (i.e., 28.9%) among the displaced persons in Nigeria. They opined that the capital was to buy equipment and establish themselves using some of the vocational trainings and skills they acquired from their various camps.



Figure 2. Suggested economic needs for voluntary return of CiIDPs, percentage.

Food, clothing, and shelter were listed by almost 26% of the respondents as part of their pre-return needs before they could be willing to go back home. About 18% of the IDPs said the reopening of markets and banks was crucial to their willingness to return while nearly 14% of them said that subsidies for farm tools, chemicals, and fertilizer were vital for their reentry. Employment as a need for returning came up again as 12.4% of the IDPs listed it as essential for them to consider going home. Lastly, but surprisingly, about 2% of them thought that street begging should be eliminated from their communities for them to be willing to return. This may be because some of the IDPs linked the issue of insecurity to street beggars and, in fact, many of the recent suicide bombers snuck into town as street beggars before detonating the bombs.

4.4. Odds of Willingness for Voluntary Return on Respondents' Selected Economic Needs

Influence in terms of the provision of selected economic needs were examined on the willingness of the displaced persons' desire to return through binary logistics regression. Three selected economic variables were used to control for willingness to return as shown in Table 3, i.e., RFA, EJO, and OCC. The odds ratio column indicates the change in the predictor variable, i.e., willingness for voluntary return or otherwise. Displaced persons

who view RFA as the highest priority for them to return home are 0.74 times less likely than those who do not view it as a priority. However, those who view it as a low priority are almost 5 times more likely to be willing to go back home than those who do not consider it as a priority. Those who consider EJO as the highest priority for their willingness to return are 1.40 times more likely than those who do not view EJO as a priority. Also, those who consider EJO high priority for reintegration are 14.11 times more likely than those who do not view it as a priority. More importantly, there is a significant relationship between employment and job opportunities back at home and willingness for a voluntary return (i.e., OR = 14.11; $p < 0.05$). OCC is the last variable examined and shows that those who consider it as their highest priority are 0.42 times less likely to be willing to return. However, those who considered OCC a low priority for their willingness to return are 3.19 times more likely to desire a return to their COO.

Table 3. Logistics regression estimating the odds of willingness to return controlling for respondents selected economic needs.

Variables and Selected Economic Needs	Level of Priority	Odds Ratio (Exp. β)	Str. Error	*p*-Value
Reintegration financial assistance	Not a priority	RC	-	-
	Low priority	4.99	1.45	0.27
	High priority	0.20	1.34	0.23
	Highest priority	0.74	0.57	0.60
Employment and job opportunities	Not a priority	RC	-	-
	Low priority	0.10	162.06	0.99
	High priority	14.11	0.90	0.003 **
	Highest priority	1.40	0.38	0.38
Opening of commercial centers	Not a priority	RC	-	-
	Low priority	3.19	16.06	0.99F
	High priority	0.21	0.94	0.10
	Highest priority	0.42	0.60	0.14
Log-likelihood		717.360		
R^2		0.376		
LR Chi^2		104.374 (df = 30)		
Prob > Chi^2		0.000		

Source: Authors' own compilation from the field survey, 2021; RC = reference category; ** $p < 0.05$.

Those who identified EJO as the highest priority for their willingness to return are 1.40 times more likely to be willing to return than those who do not view EJO as a priority for them to desire a voluntary return. Furthermore, those who consider EJO as a high priority for reintegration are 14.11 times more likely to be willing to return home than those who do not view it as a priority. More importantly, there is a significant relationship between employment/job opportunities back at home and willingness for a voluntary return (i.e., OR = 14.11; $p < 0.05$). OCC is the last variable examined, and results show that those who consider it as their highest priority to desire a return are 0.42 times less likely to be willing to return. However, those who imagine OCC as a low priority for their willingness to return are 3.19 times more likely to desire a return to their COO.

The results in the model show a Log-likelihood ratio (LLR) of 717.360, $R^2 = 37.6$, and Log Chi-square = 104.374 on 30 degrees of freedom while *p*-value = 0.001. This implies that the adjusted model summary showed that the independent variables (i.e., the selected economic characteristics) were able to explain 37.6% change in the desire of displaced persons in Nigeria to be willing to return home with an LLR of 717.360 on 30 degrees of freedom. It can, therefore, be asserted that the selected economic needs have a positive influence on the desire of CiIDPs in Nigeria for a choice of voluntary return to their COO. The overall percentage, from the regression analysis, indicates a 59.4% level of accuracy in the prediction of the outcome variable. The model summary shows 16.1% and 21.5% level

of variations in the predicted variable as explained by the independent variables given by "Cox and Snell R square" (i.e., 0.161) and "Nagelkerke R square" (i.e., 0.215). This provides confidence that this model is relevant in demonstrating the effect of respondents selected economic needs on the willingness to voluntarily return home. Overall, the statistics supported that the model correctly predicts the outcome variable by 59.4%. This implies that the planned reintegration of CiIDPs in Nigeria would not be successful and sustainable if the government does not address these economic needs and IDPs are forced to return to their COO.

5. Discussion

RFA was ranked highest (i.e., 89.4%) amongst CiIDPs' needs for voluntary return, which was not a surprise for three main reasons, among others. First, previous studies on IDPs in Africa have cited lack of money (i.e., finance) to cater for IDPs' daily life as the most prominent need [15,17]. Second, no one wants to return to their COO without a fixed source of income and resort to begging to survive. The IDPs stated that they wanted to at least settle down with some financial assistance while they transitioned to a form of gainful economic activity. Third, IOM, the largest international agency facilitating assisted voluntary return and reintegration globally, made it a statutory requirement that every returning migrant receives a minimum of USD 580 when they decide to return to their COO, especially in a post-conflict context of this nature [38]. The displaced persons in Nigeria and our respondents are yet to receive this allotment which may contribute to their unwillingness to return. Although, most of them noted they were not aware of that until the news of it started to be reported among camp personnel. They are, however, of the opinion that even if the IOM-regulated amount is not available, the government should at least provide them a little amount of money for immediate use upon their return. The Nigerian government can also use micro-credit and cooperative programs as financial strategies to facilitate IDPs access to formal financial services [7] immediately upon their return. Lack of finance to get food items and other personal needs were some of the reasons for unsuccessful reintegration and consequent protracted civil war and re-displacement among formerly displaced persons in Colombia, Uganda, Sierra Leone, and Liberia [18,40,43]. Therefore, in line with Cernea's [30] risks and risk avoidance model, it will truly be risky for displaced persons to return to their COO without any hope of livelihood. This would mean returning to hunger, hopelessness, and desperation which may not be unconnected with their apathy toward the government's plea for them to return home.

EJO was another economic variable ranked very high among the returning migrants. This is in line with previous studies which have confirmed that having a way to earn a living upon returning home is likely to guide against re-displacement as was experienced in Liberia and northern Uganda. Besides, the challenge of local hostility which returning migrants usually face in their previous communities may be reduced since they are engaged in productive economic activities [43]. Gaining employment is a challenge for displaced persons even if they choose to migrate overseas as refugees. Similarly, finding among IDPs in the Philippines showed that the need for employment and financial assistance to start a business and obtain housing was a primary challenge [22]. For example, in an empirical study by Verwiebe et al. [46], incoming refugees from the Middle East faced several challenges in obtaining employment in Austria as a result of difficulties relating to culture, language, and discrimination, among other factors. If securing employment poses a challenge to incoming migrants in a developed economy such as Austria, IDPs in in North-East Nigeria may also experience problems reintegrating to a largely agrarian society in a developing country. Displaced persons in Nigeria appear to be aware of this fact, which is why in our regression analysis, EJO was significantly related (i.e., $p < 0.05$) to a willingness to return. This implies that displaced persons will be willing to return to their COO once they are sure that they will be productively engaged which would help them make a living. One of the risks to guide against in returning IDPs to their root as discussed by Cernea [30] is social isolation. The fact is that returning migrants will not experience

such a risk if they are not productively engaged and self-sufficient which is why having something to do is very crucial upon returning to their COO.

Moreover, the high ranking of OCC is understandable since these centers were completely destroyed while others were shut down for fear of being attacked during the peak of the insurgency between 2014 and 2016. Many of them are still not opened to date. Therefore, reopening them and commencing commercial activities was viewed by the displaced people as one of the key determinants of the desire to return. This is in tandem with previous studies which link economic recovery and sustainable reintegration in post-conflict communities to resuscitation of commercial activities [40,45,47,48]. Therefore, restoration of commercial activities is a key requirement for previously displaced persons to desire a return.

Another factor ranking as very high were SAIS, which is not a big surprise, bearing in mind that North-East Nigeria is an agrarian society. Descriptive statistics from the fieldwork shows that more than half (i.e., 55.3%) of the displaced persons from the region were involved in farming. This implies that they may likely return to farming after successful reintegration. The opportunity to obtain improved seed stock, fertilizers, and other farm equipment subsidized or at lower prices are needed for them to return to farming. They will also be able to sell their farm produce in the market if commercial activities have been restored as previously discussed. As such, OCC and SAIS work side by side as far as this study is concerned. Previous studies showed that some Albanian farmers were only able to return to their COO and restart their sheep farming after they were encouraged with equipment and capital [40] while IDPs in Burundi seemed to be encouraged by the return of asset ownership including land and livestock [24]. Hence, it should be noted that displaced persons in Nigeria will be sustainably reintegrated if similar gestures are extended to them.

6. Conclusions and Recommendations

It was found that RFA, occupation back at home, reopening of commercial centers, and SAIS implementation act as the dominant economic determinants to induce willingness for voluntary return among CiIDPs in Nigeria. Suggested economic needs listed also re-emphasized the importance of some of these economic needs as they were repeated. It can be concluded that the results have implications for institutions and social agencies in Nigeria, i.e., especially the Federal Ministry of Humanitarian Affairs, Disaster Management, and Social Development, since the responsibility of caring for the displaced persons is primarily a humanitarian effort. If the Nigerian government desires to reintegrate displaced persons as promised, the appropriate agencies should equip them economically as noted in this study. The following recommendations, based on the results, are pertinent to the findings and closely intertwined with international IDP standards.

- Commercial activities should be resuscitated in the region. This will augment the regional economics of buying and selling (e.g., markets) and aid in fast-tracking a return to life pre-displacement.
- The returnees should be financially assisted in-line with IOM [38] regulation, i.e., USD 580 for every formerly displaced person who wants to return to their COO. If the entire amount is not available, a based amount should be provided by the Nigerian government, e.g., USD 290 or half of what IOM regulates.
- Economic opportunities in terms of jobs or encouragement to practice skills learned in the camp would go a long way to induce the desire of the displaced to return. This is supported by the human capital theory which posits that education and skills training increases individual capacity to become productive which, in turn, impacts their ability to secure a place in the job market and earn wages.
- Since the majority of the returnees are farmers, the Nigerian government should assist them with improved and subsidized seed stock. As found in the results, this type of assistance would help to induce their willingness for voluntary return as a large portion of the respondents work as farmers.

It is the authors' conclusion that IDPs in Nigeria will willingly return home, become engaged economically, and be sustainably reintegrated if, e.g., the Ministry of Humanitarian Affairs, Disaster Management, and Social Development, and other allied social agencies in Nigeria, collaborate with other concerned stakeholders to follow the above recommendations. Further studies should concentrate on this specific issue of how social institutions can collaborate with government agencies to evaluate and raise funds to finance reintegration, since it is a costly exercise which must be monitored and properly mitigated among interested stakeholders.

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Institutional Review Board Statement: In accordance with the Ethical Committee of the University of Gdansk, the Committee has approved the project entitled "Voluntary Return among Conflict-induced Internally Displaced Persons in Nigeria." The research and work described in the project outline is in-line and complies with the ethics of scientific research described in the Ethical Principles of the Declaration of Helsinki and other applicable ethical principles and legislation in the European Union. Inter-institutional communication with Covenant University, Nigeria, confirms the project is in accordance with the applicable ethical principles and legislation in Nigeria.

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References

1. IEP. *Global Terrorism Index 2019: Measuring the Impact of Terrorism*; Institute of Economics and Peace: Sydney, Australia, 2019.
2. UNHDR. *Global Trends: Forced Displacement in 2018*; United Nations High Commission for Refugees and United Nations Refugee Agency: Geneva, Switzerland, 2019.
3. IMO. *Assisted Voluntary Return and Reintegration: At a Glance 2015*; International Organization for Migration: Geneva, Switzerland, 2015.
4. UNOCHA. *Guiding Principles on Internal Displacement*; United Nations High Commission for Refugees and United Nations Office for the Coordination of Humanitarian Affairs: New York, NY, USA, 1991.
5. UNHDR. Policy Framework and Implementation Strategy: UNHCR's Role in Support of the Return and Reintegration of Displaced Populations. *Refug. Surv. Q.* **2009**, *28*, 205–221. [CrossRef]
6. Skran, C. Returnees in Sierra Leone. *Forced Migr. Rev.* **2008**, *1*, 29–36.
7. Chowdhury, J. Reintegration of Internally Displaced People (IDPS): The Need for Micro Credit. *Refug. Surv. Q.* **2000**, *19*, 201–215. [CrossRef]
8. Fagen, P.W. Peace Processes and IDP Solutions. *Refug. Surv. Q.* **2009**, *28*, 31–58. [CrossRef]
9. UNHCR. *Handbook for the Protection of Internally Displaced Persons*; Global Protection Cluster Working Group, United Nations High Commission for Refugees and United Nations Refugee Agency: Geneva, Switzerland, 2006.
10. Premium Times. Boko Haram: UNICEF, Yobe Government to Create Tent Classes for Displaced Children from Boko Haram: UNICEF. 10 May 2015. Available online: www.premiumtimesng.com (accessed on 22 January 2022).
11. Osagioduwa, E.; Oluwakorede, O.T. Management of Internally Displaced Persons in Africa: Comparing Nigeria and Cameroon. *Afr. Res. Rev. Int. Multidiscip. J.* **2016**, *10*, 193–210.
12. ICRC. *Internal Displacement in Nigeria: Operationalising the Kampala Convention in Borno, Adamawa and Yobe States*; International Committee of the Red Cross: Abuja, Nigeria, 2016.
13. Nyako, A.M. Concept Note on North-East Development Commission: An Institutional Framework for a Sustainable Solution to the North-East National Security Challenge. 2015. Available online: www.statehouse.gov.ng (accessed on 16 April 2018).

14. Tete, S.Y.A. Any place could be home? Embedding refugee's voices into displacement resolution and state refugee policy. *Geoforum* **2012**, *43*, 106–115. [CrossRef]
15. Olanrewaju, F.O.; Omotoso, F.; Alabi, J.O. Datasets on the challenges of forced displacement and coping strategies among displaced women in selected internally displaced persons' (IDPs) Camps in Nigeria. *Data Brief* **2018**, *20*, 152–158. [CrossRef] [PubMed]
16. Lori, J.R.; Boyle, J.S. Forced migration: Health and human rights issues among refugee populations. *Nurs. Outlook* **2015**, *63*, 68–76. [CrossRef]
17. Adekola, P.O.; Azuh, D.; Amoo, E.O.; Brownell, G. Restoration of water supply in post-conflict communities in Nigeria and sustainable reintegration. *Int. J. Civ. Eng. Technol.* **2019**, *10*, 191–201.
18. Brownell, G.; Basham, R. NGO strategy toward the reintegration of child soldiers in Liberia, Africa: An online survey of services, roles, and activities. *Int. Soc. Work.* **2017**, *60*, 1074–1086. [CrossRef]
19. Adekola, P.O.; Azuh, D.; Adeloye, D.; Amoo, E. Urban renewal in Nigeria: A slash and burn approach? *Environ. Dev. Sustain.* **2019**, *21*, 2165–2182. [CrossRef]
20. Kveder, C.L.M.; Flahaux, M.L. Returning to Dakar: A mixed methods analysis of the role of migration experience for occupational status. *World Dev.* **2012**, *45*, 223–236. [CrossRef]
21. Lukunka, B.N.; de Clercq, P. Political and economic reintegration: Key to successful return. *Forced Migr. Rev.* **2019**, *62*, 58–60.
22. Collado, Z.C. Determinants of return intentions among internally displaced persons (IDPs) of Marawi City, Philippines. *Dev. Pract.* **2020**, *30*, 113–124. [CrossRef]
23. Adekola, P.O.; Azuh, D.; Amoo, E.O. Restoration of power supply to post-conflict communities in Northern Nigeria: Implication for sustainable Reintegration of Returning Migrants. *J. Phys. Conf. Ser.* **2019**, *1299*, 012023. [CrossRef]
24. Fransen, S.; Bilgili, Ö. Who reintegrates? The constituents of reintegration of displaced populations. *Popul. Space Place* **2018**, *24*, 1. [CrossRef]
25. Tezcan, T. On the move in search of health and care: Circular migration and family conflict amongst older Turkish immigrants in Germany. *J. Aging Stud.* **2018**, *46*, 82–92. [CrossRef] [PubMed]
26. Siegel, R.M. Migration and its influence on the knowledge and usage of birth control methods among Afghan women who stay behind. *Public Health* **2018**, *158*, 183–197.
27. Brownell, G.; Praetorius, R.T. Experiences of former child soldiers in Africa: A qualitative interpretive meta-synthesis. *Int. Soc. Work* **2017**, *60*, 452–469. [CrossRef]
28. Martin-Diaz, J.; Palma, P.; Golijanin, J.; Notre, J.; Olivia, M.; Cengic, N. The urbanisation on the slopes of Sarajevo and the rise of geomorphological hazards during the post-war period. *Cities* **2018**, *76 Pt A*, 60–69. [CrossRef]
29. Catalano, H. Socio-educational consequences of the remigration phenomenon. *Proceedia Soc. Behav. Sci.* **2015**, *180*, 49–54. [CrossRef]
30. Cernea, M.M. Risks, Safeguards and Reconstruction: A Model for Population Displacement and Resettlement. *Econ. Political Wkly.* **2000**, *35*, 3659–3678.
31. Leeuwen, M.V. Crisis or Continuity? Framing land disputes and local conflict resolution in Burundi. *Land Use Policy* **2010**, *27*, 753–762.
32. Fernandes, W.; Das, C.; Rao, S. Displacement and Rehabilitation: An Estimate of Extent and Prospects. In *Development, Displacement and Rehabilitation*; Fernandes, W., Thukral, E.G., Eds.; Indian Social Institute: New Delhi, India, 1989.
33. Fernandes, W. Power and Powerlessness: Development Projects and Displacement of Tribals. *Soc. Action* **1991**, *41*, 243–270.
34. Mahapatra, L.K. Testing the Risks and Reconstruction Model on India's Resettlement Experiences. In *The Economics of Involuntary Resettlement: Questions' and Challenges*; Cernea, M., Ed.; The World Bank: Washington, DC, USA, 1999.
35. Adekola, P.O.; Azuh, D.; Amoo, E.O.; Olusanmi, O. Special appellation of special care? A quantitative analysis of the challenges facing development-induced internally displaced persons in Ogun State, Nigeria. *Osun Geogr. Rev.* **2020**, *3*, 10–21.
36. Ann, N. Amartya, K. sen and social exclusion. *Dev. Pract.* **2007**, *17*, 249–255. [CrossRef]
37. Gerry, R.; Gore, C.; Figueiredo, J.B. (Eds.) *Social Exclusion: Rhetoric, Reality, Responses*; International Institute for Labour Studies: Geneva, Switzerland, 1995.
38. IMO. *All Site Profile of IDPs Camps-Adamawa, Bornu & Yobe States*; International Organization for Migration: Geneva, Switzerland, 2018; Available online: https://displacement.iom.int/nigeria (accessed on 17 March 2018).
39. Enitan-Matthews, T. 700,000 IDPs Registered So Far-NEMA. Daily Post. 20 March 2014. Available online: https://dailypost.ng/2014/11/20/700000-idps-registered-far-nema (accessed on 27 April 2020).
40. Kaplan, O.; Nussio, E. Community counts: The reintegration of ex-combatants in Colombia. *Confl. Manag. Peace Sci.* **2015**, *35*, 132–153. [CrossRef]
41. Maduka, E.I. Responses to Ecological Disaster Induced Displacement in Anambra State. Unpublished Thesis, University of Ibadan, Ibadan, Nigeria, 2012.
42. UNHDR. *Global Trends: Forced Displacement in 2020*; United Nations High Commission for Refugees and United Nations Refugee Agency: Geneva, Switzerland, 2021.
43. Lakor, A.A.; Denov, M. When war is better than peace: The post-conflict realities of children born of wartime rape in northern Uganda. *Child Abus. Negl.* **2017**, *65*, 255–265.
44. Awodola, B. An examination of methods to reintegrate former child soldiers in Liberia. *Intervention* **2012**, *10*, 30–42. [CrossRef]

45. Subedi, D.B. Conflict, Combatants and Cash: Economic Reintegration and Livelihoods of Ex-combatants in Nepal. *World Dev.* **2014**, *59*, 238–250. [CrossRef]
46. Verwieber, R.; Kittel, B.; Delinger, F.; Liebhart, C.; Schiestl, D.; Haindorfer, R.; Liebdl, B. Finding your way into employment against all odds? Successful job search of refugees in Austria. *J. Ethn. Migr. Stud.* **2019**, *45*, 1401–1418. [CrossRef]
47. Tortorici, G.; Fiorito, F. Building in post-war environments. *Procedia Eng.* **2017**, *180*, 1093–1102. [CrossRef]
48. Nnam, M.U.; Arua, M.C.; Otu, M.S. The use of women and children in suicide bombing by Boko Haram Terrorist Group in Nigeria. *Aggress. Violent Behav.* **2018**, *42*, 35–42. [CrossRef]

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Evaluating Labour Market Flexibility Using the TOPSIS Method: Sustainable Industrial Relations

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Abstract: This study evaluates labour market flexibility using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision analysis (MCDA) method. TOPSIS is employed by comparing spatial (i.e., different countries) and temporal (i.e., long-time horizon) terms. Sustainable industrial relations processes are considered in shaping the flexibility of the labour market in 15 European Union Member States from 2009 to 2018. Countries are grouped into classes to provide a basis for benchmarking results against social and employment policies implemented at the national level. A five-step quantitative MCDA method is formulated using published data from the Organisation for Economic Co-operation and Development. The results indicate that the TOPSIS method is an appropriate approach for measuring labour market flexibility internationally. Moreover, in relation to workforce phenomena, the findings show that the method offers the possibility of examining the impact of particular factors related to social and employment policies of a country in terms of sustainable development and socioeconomic growth. The lack of precision tools to forecast the development of national and transnational labour markets—particularly during the COVID-19 era—highlights the importance of such a method for workforce planners and policymakers. Developing sustainable industrial relations in terms of associated national externalities is the motivation of the research.

Keywords: economic development; sustainable economy; multi-criteria decision analysis; labour policy; benchmarking; COVID-19 reset; EU-15

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1. Introduction

One of the needs of a modern knowledge-based economy is a flexible labour market. Dynamic technological progress and information and communication technology (ICT) development can affect the labour market and contribute to the reduction of inequalities in different labour-oriented activities (e.g., wages, income, working conditions, job security, career prospects and other work-related circumstances). The challenge of balancing the flexibility of employers with the protection of worker interest is a core element of labour market effectiveness. In the context of the current pandemic and its effects on the workforce, the concern of labour market flexibility is of particular importance. The use of tools to allow for an ex-post benchmarking of flexibility across countries and, at some point, the examination of the effectiveness of public policies to aid in best practices across markets will be crucial in building sustainable industrial relations in a post-COVID-19 era. The importance of flexibility for a smooth functioning labour market is emphasised in several studies. Documents from the European Union (EU), International Labour Organization (ILO) and strategies outlined by individual countries indicate the flexibility of labour markets as priority aspects of social and economic development. Numerous international organisations are making efforts to study how labour markets, in particular businesses, adapt to reforms and external factors (i.e., the current pandemic) to evaluate the importance of the labour market flexibility process [1,2]. Labour market flexibility is an important aspect

of the economic pillar when considering the United Nations Sustainable Development Goals (SDGs) 2030 agenda, i.e., with particular emphasis on SDG 5, 8, 10 and 17 [3,4]. Flexibility can maximize stakeholder benefits and aid in creating an overall better functioning labour market. Importantly, flexibility measures that centre themselves on increasing employment opportunities for the disadvantaged (e.g., women, elderly and people with disabilities) can create a significant impact on the labour market and, in turn, limit the occurrence of economic inequality [5–7]. Respectively, local development and interregional cooperation must be mutually compliant; however, the lack of tools, at present, significantly limits the prospect of designing effective development activities [8,9]. The tool proposed in this paper contributes not only to the general development of economic science, but specifically to the betterment of planned activities in the field of functional domestic labour markets. To better assess design effectiveness, measuring the level of labour market flexibility is explored. This exercise, in theory, should support enhanced sustainable development of the workforce by building a more harmonious labour-market-flexibility-centric society.

In general, labour market flexibility may be defined as the ability of the labour market to adapt to changing economic conditions. The importance of labour market flexibility for economic development was recognized in various economic theories, starting from classical and neoclassical (e.g., the concepts of Pigou, Haberler and Samuelson), Keynesian, through the theory of the natural rate of unemployment proposed by Friedman [10] and non-accelerating inflation rate of unemployment, i.e., first introduced as non-inflationary rate of unemployment by Modigliani and Papademos [11]. Labour market flexibility has both macroeconomic and microeconomic dimensions. The common feature of both dimensions is flexibility is defined through deregulation. Deregulation of the labour market consists in making it more flexible as a result of limiting state intervention and increasing the freedom of entrepreneurs in employee policies. The concept of labour market flexibility refers primarily to three main components: labour supply, labour demand and labour price. The flexibility of labour demand is understood as employment flexibility, labour supply flexibility as labour market mobility and labour price flexibility as wage flexibility. Institutional factors understood as industrial relations processes determine the flexibility of the labour market. Moreover, there is also the idea of the offensive and defensive approach (see Lagos [12]). The traditional defensive approach is based on the view that labour markets are excessively regulated so that it postulates deregulation while the offensive (i.e., active) approach stresses the need to provide the workforce with training and new skills in order to facilitate their adaptability to changes.

In 2020, under the conditions of COVID-19, labour market flexibility research has found a special, new dimensional trait. The ILO has released preliminary assessments on the first effects of COVID-19 on labour markets, including a growth in unemployment between 5.3 million jobs in a low scenario to 24.7 million in a high scenario, as well as a decline in labour income and increase in extreme and moderate working poverty [13]. During this period (i.e., an imminent global economic crisis and uncertainty), greater labour market flexibility could have encouraged more inclusive labour force participation provided that structural changes including work security measures were carried out in parallel. As in their report, published in 2020, the European Foundation for the Improvement of Living and Working Conditions has identified challenges and policy approaches to find the right balance between flexibility and security in the labour market [14]. Hence, the 'flexicurity' (i.e., flexibility + security) concept is closely reflected. It is a complex and multifaceted phenomenon and is yet to be soundly and well-developed as an indicator-monitoring-based framework [15]. It seems to be more political, at the moment, as noted in a number of EU policy documents (e.g., in the Europe 2020 programme of the EU or the EU Agenda in 2019–2024) rather than a socioeconomic real model (i.e., "the EU should ensure that the labour market regulatory framework provides the right balance of flexibility and security for companies and workers, facilitates job creation and does not stifle innovation" [16]. Furthermore, it should be mentioned that the EU's level flexicurity concept has been changing every year with the only countries that show positive achievements being Denmark

and the Netherlands. The Danish concept of flexicurity is based on the "golden triangle", which consists of three elements: flexible labour market, active state policy and social security [17,18]. The Dutch flexicurity model has been designed to serve the hybrid goal of, on the one hand, increasing the security of workers employed via atypical contracts (i.e., deviating from the standard open-ended employment relationship), while, on the other hand, preserving flexibility in the labour market [19]. The experience of these countries will be particularly important in terms of seeking optimal solutions in the post-pandemic period in terms of implementing a flexible labour market to ensure work security for the mutual benefit of employers and employees. To find the right balance, it is essential to have adequate and reliable historical data. Therefore, the question of measuring flexibility is important not only from a scientific point of view but also from a practical point of view.

To enhance labour market flexibility, via measurable means, the proper tools are required. The methods of measuring such phenomenon have been conducted for several decades [9,20]. They vary in character, due to their development, by including adopted components and scope-specific analyses (e.g., monomial measures that consider only one variable versus others that create a set of quantitative and qualitative factors). The methods of measuring labour market flexibility, despite the vastness of the research, are still insufficient. One concern is that their limitations do not allow for extended time-spatial research. In a European context, this is necessary to diagnose the correct performance of European labour markets as well as conduct a common pro-employability policy for the EU. Moreover, it is difficult to identify impact-relating factors that stimulate flexibility. Examination of the correlation between ICT, social and economic changes, as well as individual components via a synthetic labour market measure, can allow for the assessment of stimulant and destimulant valuation [21,22]. Furthermore, the lack of precise tools that can comparatively analyse such phenomena significantly limits the possibility of forecasting the development of national and transnational labour markets—making this research vital to workforce planners and policymakers.

The limitations of existing methods have led researchers to search for new approaches to assess the level of labour market flexibility. In this respect, synthetic measures seem to be one of the most comprehensive—since they are some of the most important factors affecting flexibility. The extent of the literature on this topic is poor, and there are no widespread best practices. The methods that are most used have time and space constraints on the data. Scholars often use their own indicators, which does not ensure the comparability of the results as well as limits that not only kerb cognitive value but, indirectly, restrict the development of the field and hamper in reaching the SDG targets. As such, this gap makes it necessary to develop new synthetic measures for labour market flexibility by improving the validation and dissemination of both the procedure and research results of the market labour flexibility process. The aim of the study is to show that under the terms of imperfect methods of evaluating labour market flexibility, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision analysis (MCDA) method, can be applied to positively compare spatial (i.e., different countries) and temporal (i.e., long-time horizon) terms. The aptitude to assess sustainable industrial relations processes allows us to consider their role in shaping the flexibility of the labour market on an international scale. In this study, this scale is specific to the EU-15 group (i.e., the Member States before 2004).

2. Materials and Methods

2.1. Hypotheses Development

In our study, we formulated two research questions (RQ), a primary hypothesis (PH) and two sub-hypotheses (SH). The research questions asked the following:

- RQ1: What are the methods and indicators of measuring labour market flexibility?
- RQ2: What are the gaps in measuring labour market flexibility?

The PH of the research explored whether TOPSIS is an effective method of examining labour market flexibility. The two sub-hypotheses followed-up on the PH by looking at whether:

- SH1: TOPSIS makes it possible to measure labour market flexibility in spatial and temporal dimensions;
- SH2: TOPSIS can be used in situations of scarcity of complete data and rely only on publicly available reliable and comparable sources.

At the first stage of the research, we reviewed methods of testing labour market flexibility and approaches previously used. We also assessed the shortcomings and deficiencies of these methods and developed the main research hypothesis based on the assumption that the TOPSIS method can be effective in examining labour market flexibility. Secondly, with the intention of verifying its usefulness and applicability, the TOPSIS method was looked at in terms of measurability of flexibility in the spatial-temporal dimension and its application under conditions of limited source data.

2.2. Theoretical Considerations

Factors affecting the flexibility of the labour market have a different nature and scope. They can be divided into micro and macroeconomic aspects. Quantitative measures related to the form of work performed are listed. These are primarily work statistics (i.e., part-time, temporary, self-employed work, engagements and dismissals, hours worked, etc.) and payroll issues. Attention is drawn to the uncertainty of the impact of individual factors and different strengths of their impact. Difficulties in international comparisons are manifested in individual measures by shaping labour market flexibility in a given region [23]. The flexibility of the labour market, as noted, is a very complex phenomenon. It requires consideration of many categories of quantitative and qualitative factors. The need to comprehensively cover the most important elements results in directing researcher interest by way of synthetic measures. Their character varies depending on the scope, depth of analysis and the qualitative and quantitative nature of the adopted components. Other, more complex approaches to assessing the flexibility of the labour market can be found in the literature [24–26]. For the purpose of comparing labour market flexibility between countries, Gawrońska-Nowak and Skorupińska [27] proposed taxonomy-based indicators, where factors that stimulate and inhibit are considered in four areas: part-time employment, trade union coverage, tax wedge, and compensation rate. The choice of these institutional factors was dictated by the ambiguity in the interpretation of the other variables (i.e., scope of collective agreements, level of regulation of fixed-term employment, etc.). Another example is the Labor Market Regulation Index, with three indicators—flexibility of employment forms, regulation of employment conditions and dismissal conditions [28]. Other measures of labour market flexibility, which are mostly widespread internationally, include [29]: Labor Freedom Index (LFI) [30], Employment Protection Legislation (EPL) index [31] and Composite Indicator of Employment Protection Legislation (EPLex) index [32].

Labour market flexibility, which seems to be clearly defined, is a phenomenon that is difficult to evaluate. There is no single measurement criterion. American economist, Solow, proposed measuring labour market flexibility based on the Beveridge curve concept. It shows the relationship between unemployment and job vacancy rates [33]. However, the measure is the vacancy rate, which is not very reliable and does not consider other components of labour market flexibility. Studies that relate to the flexibility of the labour market in reality often include only one or several variables [34–36]. There is no single, dominant criterion for assessing the flexibility of the labour market. Moreover, even very categorical statements can be found in earlier studies analysing existing indicators, for example, "given the different aspects of labour market flexibility it is impossible to construct a single meaningful measure of labour market flexibility" [37].

The LFI, developed by the Heritage Foundation, is 1 of the 12 pillars of the Index of Economic Freedom [38] and 1 of the 3 components of the so-called efficiency regulators (i.e., next to business freedom and monetary freedom). Freedom with respect to the

labour market concerns the free shaping of employment relations, obtaining or changing employment on both the demand and supply sides. Legislative regulations, trade unions and state intervention may limit freedom understood in this way (i.e., 59.6% on average for the examined countries). In 2020, the overall value of this indicator compared to 2019 has not changed. However, only six variables (i.e., force participation rate has been excluded). Currently, this indicator ranges from over 90% (i.e., highest freedom rates, e.g., Singapore) to around 20% (i.e., lowest freedom, e.g., Cuba and Turkmenistan). The index consists of seven equivalent variables: ratio of minimum wage to the average value added per worker, hindrance to hiring additional workers, rigidity of hours, difficulty of firing redundant employees, legally mandated notice period, mandatory severance pay and labour force participation rate [30,39]. The data necessary to calculate the LFI are quantitative and come primarily from World Bank data from the *Doing Business* report. The most current data are used to calculate the indicator. For the 2020 edition, the state from 30 June 2019 are the latest data available.

The EPL index, developed and calculated by the Organisation for Economic Co-operation and Development (OECD), is a set of indicators illustrating the level of legislative protection of employment. It consists of protection regulations of permanent employees, specific regulations regarding group dismissals and regulations concerning temporary work. In addition, 21 additional complementary variables are analysed [31]. This indicator, due to its extent, was very comprehensive in its area. However, it was mainly limited to issues related to the intensity of employment protection. Similar assumptions regarding the need to examine employment protection are examined by EPLex index. Developed by ILO, it determines the level of employment regulations. For this purpose, over 50 variables are utilised. In the years 2009–2019, it was calculated for 103 countries. The indicator allows, in accordance with the assumed objectives, to compare legislation in the field of termination of employment regulation to include: source and scope of regulation, contract of employment, substantive requirements for dismissals, procedures for individual dismissals, collective dismissals for economic reasons, severance pay and avenues for redress [40].

Moreover, comparable conclusions are drawn from other studies on labour market functioning. The lack of comparability, the variety of factors and measures considered, as well as the different results recorded for the same examined areas are the basic accusations against the available measures. Frequent additional defects are their incompleteness, variability depending on the environmental conditions and difference in their functioning in individual countries (i.e., co-existing indicators in different countries have not only different strength of influence but also direction). These notable methodological weaknesses are indicated in papers by Kässi and Lehdonvirta [41], Klau and Mittelstadt [37], Auer [42] and Bhattacharjea [43]. The research has focused on devoting new challenges in creating labour market indicators using currently available data [44]. Problems with interpretation, despite the large amount of data available, remain unsolved.

The dissemination of existing measures gives a two-way effect. On the one hand, the results are disseminated and with them the advantages of the measures. On the other hand, the disadvantages of individual solutions are also reproduced. Due to limitations, the development of science in this direction is also stabilizing. A review of the above indicators shows some limitations, including both temporal scope (e.g., lack of or outdated data) and spatial scope (i.e., limited number of countries covered). Therefore, it seems necessary to create an indicator that, although in part, would eliminate the limitations encountered so far. From the literature, the conclusion that can be stated is that further work is needed to improve the methodology of examining labour market flexibility [45]. Furthermore, the original indicator should be based on an individual set of factors.

2.3. Practical Implications

There are many ways to analyse systems of sustainable labour relations in countries. The institutional factors that attribute particular importance for the labour market include the tax wedge, employment protection, trade union density and collective bargaining

systems. The tax wedge, measured in the percentage of labour cost, is defined as the ratio between the amount of taxes paid by an average single worker and the corresponding total labour cost for the employer [46]. The employment protection legislation evaluate the regulations on the dismissal of workers on regular contracts and the hiring of workers on temporary ones [31]. The trade union density, expressed in a percentage, corresponds to the ratio of wage and salary earners that are trade union members, divided by the total number of wage and salary earners [47]. Collective bargaining systems are key and complex labour market institutions [48] that are measured in percentages and represent the share of workers covered by valid collective agreements in force [49]. The study, based on the available measures, is varied—due to data availability. Detailed measurements in individual categories are difficult to pinpoint and maintain a high level of complexity which are mostly based on several data points (i.e., the most common measures). This approach gives the opportunity to compare test results over time and space. The widespread use of a common methodology has many advantages, including interpretability, knowledge of the meter, familiarity with the names and its design (i.e., to facilitate and encourage its use).

It is important to note that many variables originally selected for the study were not included due to a lack of data, e.g., Global Competitiveness Index (GCI), LFI, EPL index and EPLex index, as well as the share of economic short-time workers in employment. That being said, according to the World Economic Forum, GCI data are not strictly comparable over time. Even though GCI has published reports measuring country competitiveness since 1979, early data cover just 16 countries. Moreover, the Index includes fewer indicators than it does at present. Its methodology has also undergone several improvements in order to reflect the newest schools of thought specific to the development and measurement of economic growth. Hence, GCI could not be used to create the index using the TOPSIS approach. The data in Table 1 provide the basis for assessing labour market flexibility indicators used in international comparisons and time panels. The basic problems are data availability, methodological difficulties and changing significance of the constituent factors. Other authors also present a similar assessment of existing indicators [35,36,45,50]. Moreover, important practical implications of using tools to analyse labour market flexibility and their facilitation of research activities in coordination with the development of best practices also contributes to the achievement of SDGs.

Table 1. Comparison of the labour market flexibility indicators.

Indicator	Responsible Institution	Time Range	Spatial Range	Comments
GCI Flexibility	World Economic Forum	2017–2018	137 countries (28 EU countries)	The change in the counting methodology makes it possible to compare data from the 2006–2007 report, but due to the limitations of the license agreement, the data are only available from the 2008–2009 report.
EPL	OECD	2013	41 countries (21 EU countries)	According to the current calculation method, the data are not aggregated into one synthetic indicator, the available data cover a short time series, mainly in the years 2008–2013 (i.e., 6 years), no current data, a measure of legal protection of employment.
LFI	Heritage Foundation	2018	186 countries (28 EU countries)	The value of the indicator has been published annually since 2005, the values are given in relative terms, which limits their applicability, a measure of legal protection of employment.
EPLex	ILO	2012	45 countries (13 EU countries)	Data are available from 2009, a short time series (i.e., 5 years, 2009–2013), no current data, a measure of legal protection of employment.

Source: adapted from Galik (2020).

2.4. TOPSIS Approach

The TOPSIS method was first introduced by Hwang and Yoon [51]. The basic concept is that the best-chosen alternative has not only the shortest distance from the ideal solution

(i.e., the best solution) but also the longest distance from the ideal negative solution. Therefore, this method can be treated as a development of the taxonomic method proposed by Hellwig [52], where the development measure was based on comparison only with the ideal standard. Other assumptions remained unchanged [21]. The concept is widely used to solve practical decision problems [53]. It allows ranking alternatives, which makes it easier to choose the optimal variant. This is particularly important with uncertain or incomplete data [54]. Therefore, it is not surprising to use this tool often to support business management.

As an attempt to develop an original indicator based on an individual set of factors, the following solution is proposed, a synthetic labour market flexibility indicator based on the TOPSIS approach. TOPSIS is based on a linear ordering of considered objects with a list of indicators. The TOPSIS method is one of the best-known ranking methods. TOPSIS is a frequently used tool from the group of MCDA methods [55]. In recent years, the use of advanced MCDA techniques have been applied to solve complex problems [56]. These methods allow analysts to better understand the process of assessing phenomenon. It can assist in the decision-making process by providing a reliable tool to systematize information. The desire to build advanced decision models with higher decision support capabilities in a wide range of applications, promotes the integration of MCDA techniques with efficient systems, such as intelligence and expert systems and geographical information systems. The areas of a TOPSIS application can be divided into several categories. Most often, the method used to evaluate alternative solutions can relate to supply chain management and logistics activities [57]. This applies in particular to the selection of the optimal supplier [54,55,58–60] but also the right choices regarding the subject of the delivery itself [61,62]. The ranking method, taking into account the volume of data, allows for choosing the (relative) best solution. Other areas include project management [63], engineering and production systems [64], negotiation processes [65,66], business and marketing management and health, safety and environmental management. Another important area is the assessment of quality of services [67–70]. Moreover, a number of studies using the TOPSIS approach also support decision-making processes in the area of human resource management [71–74]. Finally, another relatively new area of the use of TOPSIS are various types of analyses devoted to sustainability, both for individual enterprises and comparative assessment [68,75,76].

The areas for a TOPSIS application can be divided into several categories. Most often, this method is used to evaluate alternative solutions in the supply chain of management and logistics [57]. This applies in particular to the selection of the optimal supplier [54,55,58–60] but also in developing the right choices regarding the subject of the delivery [61,62]. The ranking method, taking into account the amount of data, allows us to choose the relatively best solution. Specific areas include project management [63], engineering and production systems [64], negotiation processes [65,66], business and marketing management and health, safety and environmental management. Specifically, an important area that has grown over the last decade is the assessment of quality of services [67–70], i.e., a number of studies use the TOPSIS approach to support decision-making processes in the area of human resource management [71–74]. Another relatively new area of the use of TOPSIS are various types of analyses devoted to sustainability, both for individual enterprises and comparative assessments [68,75,76].

The specialization of the areas of analysis using the TOPSIS method is dictated by the popularity of the tool in given scientific environments. This is also evident when the geographical spread of this approach is taken into account. The scientific community has shown that it derives knowledge from its own environment; hence, the popularity of different MCDA methods is spread somewhat unevenly. The TOPSIS method is similar. It is admittedly one of the most frequently used methods of multi-criteria support for decision-making processes, but at the same time, its popularity is diverse with significant amounts of research carried out in China, Iran and Poland [56]. TOPSIS has also been used in analyses of various phenomena in such countries as Croatia [77], Canada [78], Brazil [79],

the USA [80], Bangladesh [70], Taiwan [67] and Turkey [25]. It is our conclusion that the TOPSIS approach is useful primarily for making management decisions [53]. Few studies attempt to use linear ordering models for areas that do not involve the assessment of microeconomic aspects. The question remains, is TOPSIS an effective approach of assessing the level of flexibility of labour markets and their classification according to this indicator? As it has already been stated, typical methods used to study the flexibility of the labour market do not meet analytical needs. The TOPSIS method, thanks to its advantages, reduces existing restrictions.

The key TOPSIS benefit is a consistent approach to decision making based on multiple criteria. The basic advantages of the TOPSIS method [20] are its simplicity, rationally comprehensible concept, good computational efficiency and ability to measure the relative performance for each alternative in a simple mathematical form [81]. Among many multi-criteria techniques (e.g., bipolar, VIKOR, SAW, PROMETHEE and SMART), the TOPSIS method was selected because it is one of the most frequently used methods in discrete MCDA research [82]. Simple mathematics are very important in using TOPSIS (Table 2). That is why it is relatively easy to adapt to different areas. Compared to other methods supporting the decision-making process, TOPSIS is distinguished by considering the weight of criteria used in the construction of the indicator [83,84]. This is one of the most frequently repeated advantages of this method and allows, if necessary, for more reliable results.

Table 2. Advantages of the classic TOPSIS method.

Advantage	Selected Publications
Rationality	García-Cascales and Lamata [85]; Li et al. [86]; Başdar and Alper [25]
Understandability	García-Cascales and Lamata [85]; Ginting et al. [76]; Li et al. [86]; Komlan [83]; Başdar and Alper [25]; Safari et al. [73]; Szarafinska and Fabisiak [84]
Simple mathematics—allowing for the best alternatives for each criterion to be presented in a simple mathematical form	García-Cascales and Lamata [85]; Ginting et al. [76]
Weights are included in the comparative procedures	García-Cascales and Lamata [85]
Reliability	Li et al. [86]
Effective implementation	Komlan [83]; Safari et al. [73]; Szarafinska and Fabisiak [84]
Intuitiveness of the procedure	Safari et al. [73]

Source: own elaboration.

For an effective TOPSIS application, it is necessary to select criteria for evaluation and to assign appropriate weights (i.e., if needed). For this purpose, the Analytic Hierarchy Process (AHP) method is most often used, as well as the Analytic Network Process (ANP). The applicability of using either of the described methods [59,62,63,86–89] is confirmed via their effectiveness and application potential to support real decision-making processes. There are examples of using TOPSIS to evaluate policy strategies of cities and regions based on several types of data (i.e., qualitative and quantitative) to eliminate any skewed assessment factors. The effectiveness of the methods has also been assessed by looking at development strategies at national and local levels [77], assessing the state of the environment [90,91] and assessing the financial condition or spatial diversity of regions [92–94] and quality of individual areas of public health care [95]. The TOPSIS method has also been used on a macro scale to assess the labour market environment [8,96], including its flexibility. Numerical examples [97,98] confirm TOPSIS as an appropriate method of comparing labour market flexibility between countries. TOPSIS is therefore used not only as a tool to support decision-making processes at the industrial relations level but also as a method of assessing given socioeconomic phenomena in individual areas or in comparative analysis.

The TOPSIS method also has some disadvantages and limitations. Some of them concern the method, especially the idea of a bipolar reference point, while some critical

remarks focus on supporting procedures. One of the problems attributed to TOPSIS is that its use in accordance with the assigned procedure can cause a phenomenon called rank inversion. In this phenomenon, the order of alternative preferences changes when the alternative is added or removed from the decision problem. In some cases, this can lead to so-called total rank reversal, and the best alternative may become the worst [85]. This phenomenon may, in many cases, not be acceptable. In addition, the characteristic feature, which is the need to precisely determine the weighting of the criteria and their assessments using real values, is also treated as its limitation [65].

Due to the limitations, new variants of the TOPSIS method are created, tailored to specific research needs. Despite critical comments, the effectiveness of the classic TOPSIS method in studies in various contexts has been confirmed. This indicates a tendency to increase their number and frequency of use as a tool for ranking alternatives in decision-making processes [56]. Until recently, the TOPSIS method was rarely used to study macroeconomic phenomena [25,77]. The lack of interest of this method in studying macro-scale phenomena should not come as a surprise. TOPSIS is included in the group of tools used to make decisions in a multi-criteria environment. This is not a basic assumption for macroeconomic research. However, the advantages of TOPSIS, its versatility and the ability to classify results into individual groups also suggests the possibility of its wider use. This method is particularly useful for considering the evaluation of phenomena and their categorization in groups separated according to the best assessment.

2.5. Study Scope

The study covers a period of 10 years from 2009 to 2018 for the EU-15 group (i.e., the Member States before 2004) comprising of the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom [99]. The selection of countries for the study was determined by access to data in the year of the survey (2020). All data used in the study to create the index were published by the OECD and calculated according to their measurement methodology. The established spatial and temporal scope and the selection of variables adopted for the study resulted from the timeliness, availability in reliable sources of information and comparability of data at the time of the study. The selection of variables was also determined by access to data. At first, a wide range of data, different types of indicators describing flexibility and all EU member states were considered. Due to a large number of missing data, the study was limited to the EU-15 using seven variables. After performing the calculations, the test was repeated (i.e., using a back testing procedure) with missing data imputation with similar results being obtained. This process illustrated that the TOPSIS method could be applied even with limited data availability. As such, for individual missing data, the deterministic imputation method was used based on the mean of the known values of some variable for the missing values on the same variable [100]. In the survey, administrative data were used as indicated by different research centres. In the absence of data, survey data were used, provided by research institutions. The study was compiled using Microsoft Excel 2021 in conjunction with the add-in program Analysis ToolPak. The procedure of the study is expressed in the following five steps [97,98].

1. Formal and objective choice of input measures (i.e., indicators) of labour market elasticity. The choice of input indicators was based on two criteria. First, the variance ratio is analysed in order to exclude quasi-constant variables. Second, the inverse correlation matrix is computed, and its diagonal elements are used to exclude variables exhibiting too strong a correlation with other indicators. As a result, a data matrix of dimensions (i.e., countries, indicators and years) are included in one matrix. Number of rows is equal to m*t because for each country k was made up of t entries (i.e., where: t = number of years), i.e., $m \times txn$, was created, Equation (1):

$$X = [x_{kit}] \tag{1}$$

where:
x_{kit} = value of the kth indicator of labour market elasticity (i.e., $k = 1, 2, \ldots, n$) for the ith country (i.e., $i = 1, 2, \ldots, m$) in year t (i.e., $t = 1, 2, \ldots, t$);
n = number of elasticity indicators (i.e., $n = 7$);
m = number of analysed countries (i.e., $m = 15$);
t = number of years in the analysis (i.e., $t = 10$).

2. Normalization and standardization of input indicators. These operations were performed due to indicators having different scales and values. Because during the construction of synthetic indicators input variables will be averaged, it is necessary to assure that they have the same scale (i.e., range of values) and direction (i.e., positive or negative). In order to achieve that, stimulants and destimulants were transformed into nominants. Stimulant is the variable exhibiting positive correlation with the outcome (i.e., dependent) variable. Higher values of the independent variable coincide with higher values of the dependent variable. Destimulant is the variable exhibiting negative correlation with the outcome (i.e., dependent) variable. Higher values of the independent variable coincide with lower values of the dependent variable. Nominant is the variable which is a stimulant until a certain threshold (i.e., called the nominal value). As a result, after this threshold level it becomes a destimulant. The following formulae, Equations (2)–(5), were used. For stimulants:

$$Z_{kit} = \frac{x_{kit} - \min\limits_{it}\{x_{kit}\}}{\max\limits_{it}\{x_{kit}\} - \min\limits_{it}\{x_{kit}\}} \quad (2)$$

For destimulants:

$$Z_{kit} = \frac{\max\limits_{it}\{x_{kit}\} - x_{kit}}{\max\limits_{it}\{x_{kit}\} - \min\limits_{it}\{x_{kit}\}} \quad (3)$$

For nominants:

$$Z_{kit} = \frac{x_{kit} - \min\limits_{it}\{x_{kit}\}}{\max\limits_{it}\{x_{kit}\} - \min\limits_{it}\{x_{kit}\}} \quad \text{gdy } x_{kit} \leq \text{nom}\{x_{kit}\} \quad (4)$$

$$Z_{kit} = \frac{\max\limits_{it}\{x_{kit}\} - x_{kit}}{\max\limits_{it}\{x_{kit}\} - \min\limits_{it}\{x_{kit}\}} \quad \text{gdy } x_{it} > \text{nom}\{x_{kit}\} \quad (5)$$

where:
i = number of countries (i.e., $i = 1, 2, \ldots, 15$);
k = number of input elasticity indicators (i.e., $k = 1, 2, \ldots, 7$);
t = number of years (i.e., $t = 1, 2, \ldots, 10$);
$\max\limits_{it}\{x_{kit}\}$ = maximum value of the kth indicator in year t;
$\min\limits_{it}\{x_{kit}\}$ = minimum value of the kth indicator in year t;
$\text{nom}\limits_{it}\{x_{kit}\}$ = nominal value of the kth indicator in year t.

3. Calculation of the Euclidean distance of input indicators for all the countries in a given year from pattern $z^+ = (1, 1, \ldots, 1)$ and anti-pattern $z^- = (0, 0, \ldots, 0)$ was performed using the following formulae, Equations (6) and (7):

$$d_{it}^{+} = \sum_{i=1,t=1}^{\min} \left(\sqrt{z_{kit}} - z_{it}^{+}\right)^2 \quad (6)$$

$$d_{it}^{-} = \sum_{i=1,t=1}^{\min} \left(\sqrt{z_{kit}} - z_{it}^{-}\right)^2 \quad (7)$$

where:
i = number of countries (i.e., i = 1, 2, . . . , 15);
k = number of input elasticity indicators (i.e., k =1, 2, . . . , 7);
t = number of years (i.e., t = 1, 2, . . . , 10).

The countries were ordered according to their distance from an ideal object, i.e., first, an ideal object (optimal values of all the variables) is chosen, and then, for each country, a distance from this object is computed. In the computation of distance, all the factors had an equal weight of one. Objects were grouped according to the distance.

4. Calculation of the synthetic measure of labour market elasticity in the TOPSIS methodology utilises Equation (8). The synthetic measure takes values $q_{it} \in [0 : 1]$. Higher values indicate higher elasticity of the labour market. Analysis of changes of q_{it}. in time allows to assess the dynamics of labour market elasticity within time and, in comparison, to other countries:

$$q_{it} = \frac{\mathrm{d}_{it}^{-}}{d_{ti}^{-} + d_{it}^{+}} \tag{8}$$

where:
i = number of countries (i.e., i = 1, 2, . . . , 15);
t = number of years (i.e., t = 1, 2, . . . , 10).

5. Linear ordering and classification of the analysed Member States was performed according to their labour market elasticity. Classification was conducted based on the values of the synthetic indicator. Classes were established based on the mean and standard deviation of the synthetic indicator using the following thresholds, Equations (9)–(12):

Class I (i.e., high labour market elasticity):

$$q_i \geq \overline{q} + s_q \tag{9}$$

Class II (i.e., medium high labour market elasticity):

$$\overline{q} + s_q > q_i \geq \overline{q} \tag{10}$$

Class III (i.e., medium low labour market elasticity):

$$\overline{q} > q_i \geq \overline{q} - s_q \tag{11}$$

Class IV (i.e., low labour market elasticity):

$$q_i < \overline{q} - s_q \tag{12}$$

where:
q_i = mean of the synthetic indicator of labour market elasticity;
s_q = standard deviation of the synthetic indicator of labour market elasticity.

The synthetic indicator of labour market flexibility was calculated using seven variables: tax wedge, trade union density, unemployment rate, temporary employment, part-time employment rate, employment rate by age group 15–24 and employment rate by age group 55 to 64. Table 3 presents a set of all variables used in the study with a description of the unit of measurement [101–106]. The selection of variables was based on formal and substantive criteria. Measuring the flexibility of the labour market is possible only through the analysis of various measures and the interdependence of broad economic indicators [107]. As previously reported in the literature, the following factors have a high impact on the labour market: tax wedge, employment protection, unemployment benefits, trade unions and centralisation or decentralised wage bargaining. The set of variables indicated in previous research of labour market flexibility [97,98] were also considered. The selection of

variables for the study was determined by access to data. A number of variables originally selected for the study were not included due to lack of data, including flexibility—labour market efficiency—Global Competitiveness Index, LFI, EPL index, EPLex index and share of economic short-time workers in employment.

Table 3. Variables of the labour market flexibility qualified for the study.

Variable Designation	Variable Description	Description of Measure Unit
x_1	Tax wedge	The ratio between the amount of taxes paid by an average single worker and the corresponding total labour cost for the employer. The indicator is measured in percentage of labour cost [101].
x_2	Trade union density	The ratio of union members divided by the total number of employees. The database contains information from administrative and survey data. Administrative data were mainly used in the present study. The indicator is measured in percentage of total employment [102].
x_3	Unemployment rate	The ratio between unemployed people and the labour force. The indicator is measured in percentage of labour force [103].
x_4	Temporary employment	Temporary employment includes wage and salary workers whose job has a pre-determined termination date. The indicator is measured in percentage of dependent employment [104].
x_5	Part-time employment rate	The proportion of persons employed part-time among all employed persons. The indicator is measured in percentage of employment [105].
x_6	Employment rate by age group 15–24	The employment rate for a given age group is measured as the number of employed people of a given age as a percentage of the total number of people in that same age group. Employment rates are shown for age groups, e.g., people entering the labour market following education aged 15 to 24 and people passing the peak of their career and approaching retirement aged 55 to 64. This indicator is measured as a percentage in that same age group [106].
x_7	Employment rate by age group 55–64	Safari et al. [73]

Source: own elaboration.

Labour market flexibility variables were divided into stimulants and destimulants. Three of these variables were considered destimulants: tax wedge, trade union density and unemployment rate. An increase in the value of these variables led to a decrease in labour market flexibility. The following four variables were considered stimulants: employment rate of temporary workers, share of part-time workers, employment rate of younger workers aged 15–24 and employment rate of older workers aged 55 to 64. An increase in the value of these variables led to an increase in labour market flexibility. A similar selection of variables was used in other research studies [97,98]. Statistical data of the indicators selected for the study allowed to calculate the synthetic index of labour market flexibility for each country in each year, according to the procedure of the TOPSIS method (i.e., dynamic evaluation). All data were collected and converted in 2020. Table 4 presents the values of the labour market flexibility index in the EU-15 in 2009 to 2018.

Table 4. Values of the synthetic index of labour market flexibility in the EU-15 in 2009–2018 using the TOPSIS method.

No.	Country †	Year										Average from 2009–2018
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
1	Austria	0.481	0.493	0.493	0.499	0.503	0.505	0.499	0.509	0.509	0.506	0.500
2	Belgium	0.288	0.291	0.321	0.326	0.324	0.322	0.321	0.326	0.331	0.348	0.320
3	Denmark	0.510	0.501	0.507	0.507	0.508	0.513	0.521	0.565	0.555	0.544	0.523
4	Finland	0.422	0.438	0.457	0.476	0.473	0.464	0.452	0.459	0.465	0.481	0.459
5	France	0.432	0.442	0.454	0.472	0.488	0.484	0.485	0.479	0.483	0.473	0.469
6	Germany	0.549	0.577	0.597	0.599	0.605	0.601	0.594	0.596	0.595	0.588	0.590
7	Greece	0.396	0.383	0.333	0.310	0.311	0.325	0.332	0.325	0.320	0.316	0.335
8	Ireland	0.531	0.507	0.508	0.519	0.536	0.544	0.558	0.579	0.579	0.585	0.545
9	Italy	0.366	0.364	0.377	0.385	0.379	0.379	0.386	0.388	0.392	0.392	0.381
10	Luxembourg	0.439	0.437	0.433	0.444	0.432	0.433	0.439	0.423	0.434	0.427	0.434
11	Netherlands	0.751	0.758	0.767	0.797	0.792	0.808	0.814	0.814	0.826	0.820	0.795
12	Portugal	0.526	0.516	0.508	0.501	0.491	0.492	0.495	0.501	0.510	0.523	0.506
13	Spain	0.457	0.449	0.454	0.449	0.452	0.456	0.475	0.487	0.494	0.495	0.467
14	Sweden	0.479	0.496	0.520	0.523	0.528	0.528	0.523	0.521	0.520	0.513	0.515
15	United Kingdom	0.576	0.581	0.583	0.594	0.601	0.610	0.615	0.622	0.619	0.615	0.602

† list of countries in alphabetical order. Source: based on OECD [101–106].

3. Results

The research allowed a comparison of the economies based on a 10-year time series (Table 5). The Netherlands was the country with the highest labour market flexibility, while Belgium scored the lowest. All the countries were classified into four types according to the level of labour market flexibility. In Class I, with high labour market flexibility, there was one country, the Netherlands. In Class II, with average labour market flexibility, there were seven countries: the United Kingdom, Germany, Ireland, Denmark, Sweden, Portugal and Austria. In Class III, with below-average labour market flexibility, there were five countries: France, Spain, Finland, Luxembourg and Italy. In Class IV, with low labour market flexibility, there were two countries: Greece and Belgium.

Table 5. Linear order and typology (i.e., Class) according to the average value of synthetic index of labour market flexibility for EU-15 in 2009–2018 using the TOPSIS method.

Labour Market Flexibility	Type (i.e., Class)	Value of the Synthetic Index of Labour Market Flexibility †	Country	Mean Value of the Synthetic Index of Labour Market Flexibility	Averages Values
high	I	>0.612	Netherlands	0.795	0.496
Medium high	II	0.496–0.612	United Kingdom	0.602	0.496
			Germany	0.590	0.496
			Ireland	0.545	0.496
			Denmark	0.523	0.496
			Sweden	0.515	0.496
			Portugal	0.506	0.496
			Austria	0.500	0.496
Medium low	III	0.379–0.496	France	0.469	0.496
			Spain	0.467	0.496
			Finland	0.459	0.496
			Luxembourg	0.434	0.496
			Italy	0.381	0.496
Low	IV	<0.379	Greece	0.335	0.496
			Belgium	0.320	0.496

† based on $\overline{q} = 0.496$, $s_q = 116$, $\overline{q} + s_q = 0.612$, $\overline{q} - s_q = 0.379$. Source: based on OECD [101–106].

Figure 1 presents mean values of the synthetic labour market flexibility index in the EU-15 countries from 2009–2018, calculated using the TOPSIS approach. Above the average value there were the countries from the first and second type (i.e., eight countries). The countries from the third and fourth type (i.e., seven countries) were below the average. The results of such calculations can be used for further causal or correlative studies relating to labour market policies and labour market flexibility. Various databases collecting information on labour market reforms can be used, such as LABREF, managed by the European Commission in cooperation with the Employment Committee [108], as well as other international or national data sources.

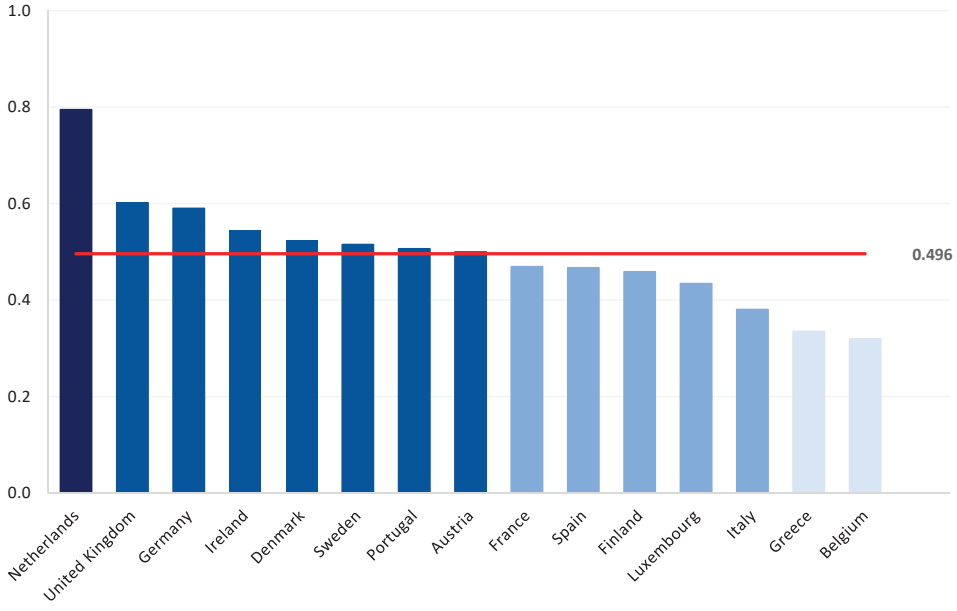


Figure 1. Average values of the synthetic labour market flexibility index in the EU-15 countries from 2009–2018 using the TOPSIS method. Note: The graph follows the order of flexibility, with countries with the most flexible labour markets on the left-hand side and those with the lowest flexibility rating on the right-hand side. The graphs show the arithmetic mean of data reported for the EU-15, divided into four typological classes according to the flexibility of the labour market, marked with the colour of the column. The more intense the blue colour, the more flexible the labour market is according to the mean value of the synthetic labour market flexibility index in the EU-15 in 2009 to 2018. The average arithmetic value was marked by red line. Source: based on OECD [101–106].

Analysing the percentage change in the mean value of the synthetic index of labour market flexibility in the EU-15 countries between the data for 2009 and 2018 (Figure 2), the largest increases in value were recorded in Belgium, Finland and Ireland. Decreases in value were noted in Greece, Luxembourg and Portugal. The analysis of the percentage changes in a given period can also be used to investigate the abovementioned relationships but can also be an effective tool to compare changes between countries for given periods when there are common external drivers, such as the COVID-19 pandemic.

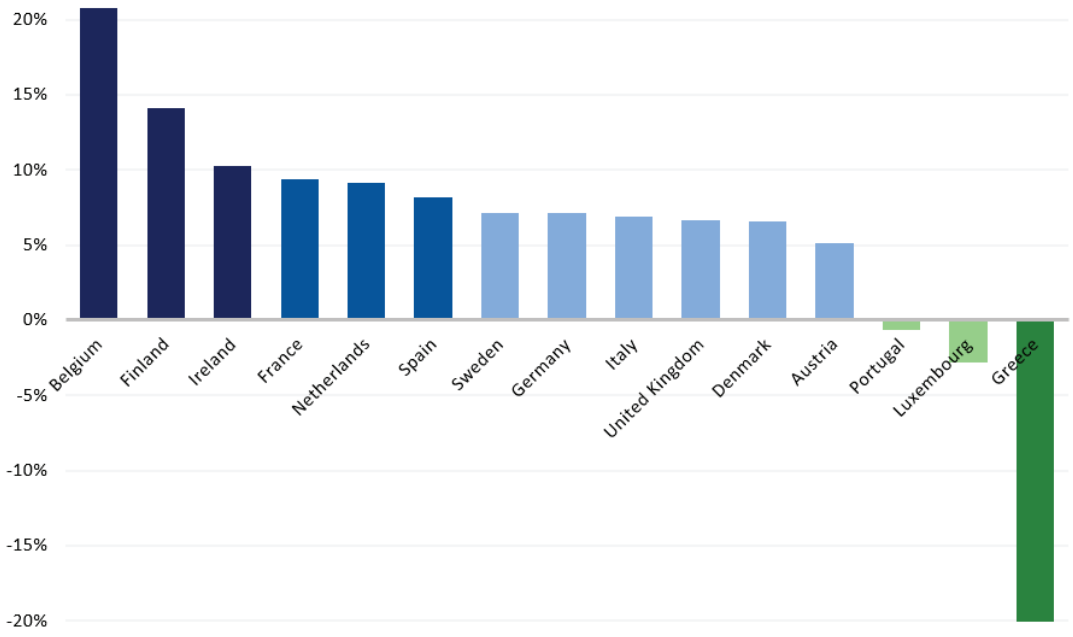


Figure 2. Percent change (i.e., increase/decrease) in the average value of the synthetic labour market flexibility index in the EU-15 in 2009 and 2018 using the TOPSIS method. *Note*: increase/decrease in percentage = [(index value in 2018 − index value in 2009)/index value in 2009] × 100%; order of data from the country with the highest percentage increase in labour market flexibility to the country with the highest percentage decrease in labour market flexibility. Source: based on OECD [101–106].

4. Discussion and Conclusions

Building a sustainability-based, synthetic measure of labour market flexibility, the use of the TOPSIS approach has made it possible to compare the EU-15 countries in a given period. The results indicate that in the analysed countries there are different levels of labour market flexibility. Grouping countries into classes provides a convenient basis for benchmarking the results against policies at the national level. The research may be a good basis to further engage the relationship and our understanding of comparing workforce-related phenomenon. The lack of precision tools to forecast the development of national and transnational labour markets—particularly during the COVID-19 era—can elevate and aid workforce planners and policymakers alike to rethink industrial relations. There is already a diverse opinion in the scientific and media world about the consequences of the pandemic. There is also a lack of indicators to help diagnose and forecast possible solutions for economic and social policies. TOPSIS is an appropriate approach for measuring labour market flexibility on an international scale that offers the possibility to examine the impact of particular elements of social and employment policies of a country in terms of sustainable development and socioeconomic growth of regions and countries. This can empower respective entities (e.g., government agencies) to forecast sustainability-focused industrial relations and changes as a result of future unforeseen risks with similar effects via isolation and the freezing of economies [109,110]. In the age of globalisation, this seems to be an important analytical factor [111,112].

Future research could conduct detailed studies of the evaluation of labour market flexibility in individual EU countries with a higher level of resolution by examining correlative domestic labour market values. On this basis, it would be possible to determine at the national level which determinants have the greatest impact on shaping the flexibility of the labour market and the direction of their influence. A key question being, what can

help to find the best solutions tailored to the current problems and needs of the labour market itself? This would make it possible to determine which of the components of the synthetic labour market flexibility index proposed by Galik [29] would be most important in shaping flexibility and in which of them a positive correlation could be found. Such studies point to those elements of the functioning of the labour market which have the greatest potential to make domestic labour markets more flexible [19,113,114]. From an implementation point of view, it may constitute the basis for building a sustainable social and economic development strategy based on flexible labour markets. It may also indicate the most optimal tools for returning to the state of equilibrium in moments of economic and labour market fluctuations. A noteworthy limitation, however, is that the TOPSIS approach is not widely used in labour market flexibility research. This, in turn, means that we do not have extensive comparative material. Nonetheless, studies available so far [29,97,98] confirm the reliability of the method. Moreover, the research gives convergent results and indicates wide possibilities of dissemination of the approach among labour market researchers. In all, the availability of data for time-space analysis on the components of the synthetic labour market flexibility meter is still limited—a problem for all the available indicators. In TOPSIS, this problem has been significantly reduced; however, the lack of data still significantly limits the possibility of extending the temporal and spatial studies.

Furthermore, the limitations in the availability of statistical data necessary for spatial and temporal analysis are an important barrier to research in the field of labour market flexibility. The smaller number of variables considered may suggest some difficulties in implementing the conclusions drawn up on the basis of the study. Therefore, when a greater number of reliable data sources, tailored to the needs of spatial-temporal analysis, are available, re-verifying the model output should allow for higher resolution results as well as for better statistical examination.

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References

1. European Central Bank Wage Dynamics Network (WDN). Available online: https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_wdn.en.html (accessed on 10 October 2021).
2. European Commission. *Labour Market Adjustments during the Crisis and the Role of Flexibility*; European Commission: Brussels, Belgium, 2018.
3. Van Tulder, R.; Rodrigues, S.B.; Mirza, H.; Sexsmith, K. The UN's Sustainable Development Goals: Can multinational enterprises lead the Decade of Action? *J. Int. Bus. Policy* **2021**, *4*, 1–21. [CrossRef]
4. United Nations Sustainable Development Goals. Available online: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (accessed on 3 May 2019).
5. Hay, I. *Geographies of the Super-Rich*; Edward Elgar: Cheltenham, UK, 2013; ISBN 0857935682.
6. Boldrin, M.; Canova, F.; Pischke, J.-S.; Puga, D. Inequality and Convergence in Europe's Regions: Reconsidering European Regional Policies. *Econ. Policy* **2001**, *16*, 205–253. [CrossRef]
7. Joshi, R. Assessing the Impact of Income Inequality on Economic Growth. *Indian Econ. J.* **2017**, *65*, 1–26. [CrossRef]

8. Ali, F.M.; Ezatollach, L.; Malihe, R. Regional Differences in the Work Market in Urban Areas. *Hum. Geogr. Res. Q.* **2016**, *47*, 645–655.
9. Ghaleb, A.M.; Kaid, H.; Alsamhan, A.; Mian, S.H.; Hidri, L. Assessment and Comparison of Various MCDM Approaches in the Selection of Manufacturing Process. *Adv. Mater. Sci. Eng.* **2020**, *2020*, 4039253. [CrossRef]
10. Friedman, M. The Role of Monetary Policy. *Am. Econ. Rev.* **1968**, *58*, 1–17.
11. Modigliani, F.; Papademos, L. Targets for Monetary Policy in the Coming Year. *Brook. Pap. Econ. Act.* **1975**, *1975*, 141. [CrossRef]
12. Lagos, R.A. Labour market flexibility: What does it really mean? *CEPAL Rev.* **1994**, *1994*, 81–95. [CrossRef]
13. ILO. *COVID-19 and the World of Work: Impact and Policy Responses*; International Labour Organisation: Geneva, Switzerland, 2020.
14. Weber, T.; Hurley, J.; Mandl, I.; Bisello, M.; Vacas-Soriano, C. *Labour Market Change: Trends and Policy Approaches towards Flexibilisation*; Publications Office of the European Union: Luxembourg, 2020.
15. De Pedraza, P.; Álvarez-Díaz, M.; Domínguez-Torreiro, M. Sympathy for the devil? Exploring flexicurity win–win promises. *IZA J. Labor Policy* **2019**, *9*. [CrossRef]
16. Business Europe. *Prosperity People Prosperity Planet. Three Pillars for the EU in 2019–2024*; Business Europe: Brussels, Belgium, 2019.
17. Bredgaard, T.; Larsen, F.; Madsen, P.K. Flexicurity: In Pursuit of a Moving Target. *Eur. J. Soc. Secur.* **2008**, *10*, 305–323. [CrossRef]
18. Bonoli, G.; Madsen, P.K. The Danish Model of Flexicurity: A Paradise—With Some Snakes. In *Labour Market and Social Protection Reforms in International Perspective*; Routledge: Oxfordshire, UK, 2018; pp. 243–265.
19. Bekker, S.; Mailand, M. The European flexicurity concept and the Dutch and Danish flexicurity models: How have they managed the Great Recession? *Soc. Policy Adm.* **2019**, *53*, 142–155. [CrossRef]
20. Olson, D.L. Comparison of weights in TOPSIS models. *Math. Comput. Model.* **2004**, *40*, 721–727. [CrossRef]
21. Balcerzak, A.; Pietrzak, M. Wpływ efektywności instytucji na jakość życia w Unii Europejskiej. Badanie panelowe dla lat 2004–2010. *Prz. Stat.* **2015**, *1*, 71–91.
22. Hajduk, S.; Jelonek, D. A Decision-Making Approach Based on TOPSIS Method for Ranking Smart Cities in the Context of Urban Energy. *Energies* **2021**, *14*, 2691. [CrossRef]
23. Beatson, M. *Labour Market Flexibility. Employment Market Research Unit*; Employment Department, Research Strategy Branch: London, UK, 1995.
24. Kozera, A. Financial self-sufficiency of the metropolises in 2007–2015. *Stud. Reg. Lokal.* **2018**, *71*, 82–105. [CrossRef]
25. Başdar, C.; Alper, D. A Comparison of TOPSIS and ELECTRE Methods: An Application on the Factoring Industry. *Bus. Econ. Res. J.* **2017**, *8*, 627–646. [CrossRef]
26. Paradowski, B.; Wieckowski, J.; Dobryakova, L. Why TOPSIS does not always give correct results? *Procedia Comput. Sci.* **2020**, *176*, 3591–3600. [CrossRef]
27. Gawrońska-Nowak, B.; Skorupińska, K. Elastyczność rynku pracy a charakter instytucji w krajach europejskich. *Gospod. Nar.* **2006**, *206*, 23–40. [CrossRef]
28. Boni, M.; Piotrowski, B.; Radziwłł, A.; Rusielewicz, A.; Sowa, A.; Sztanderska, U.; Walewski, M.; Wojnarowski, J. Elastyczny rynek pracy w Polsce. Jak sprostać temu wyzwaniu? *Zesz. BRE Bank–CASE* **2004**, *73*, 7–121.
29. Galik, A. *Wpływ Nowych Technologii na Elastyczność Rynku Pracy*; University of Gdańsk: Gdańsk, Poland, 2020; ISBN 978-83-7865-930-3.
30. Heritage Foundation Labor Freedom. Available online: https://www.heritage.org/index/labor-freedom (accessed on 9 October 2021).
31. OECD OECD Indicators of Employment Protection. Available online: https://www.oecd.org/employment/emp/oecdindicatorsofemploymentprotection.htm (accessed on 12 October 2021).
32. ILO Employment Protection Legislation Database—EPLex. Available online: https://eplex.ilo.org (accessed on 9 October 2021).
33. Solow, R.M. *What Is Labour-Market Flexibility? What Is It Good for?* The British Academy: London, UK, 1998; pp. 189–211.
34. Bande, R.; Karanassou, M. Labour market flexibility and regional unemployment rate dynamics: Spain 1980–1995. *Pap. Reg. Sci.* **2009**, *88*, 181–207. [CrossRef]
35. Kiander, J.; Virén, M. Measuring labour market flexibility in the OECD countries. *Empirica* **2001**, *28*, 187–201. [CrossRef]
36. Monastiriotis, V. A Panel of Regional Indicators of Labour Market Flexibility: The UK, 1979–1998. In *The European Labour Market. AIEL Series in Labour Economics*; Caroleo, F.E., Destefanis, S., Eds.; Physica-Verlag HD, Elsvier: Amsterdam, The Netherlands, 2006; pp. 221–244. [CrossRef]
37. Klau, F.; Mittelstadt, A. Labour Market Flexibility. *OECD Econ. Stud.* **1986**, *6*, 7–45.
38. Miller, T.; Kim, A.B.; Roberts, J.M. *2020 Index of Economic Freedom*; The Heritage Foundation: Washington DC, USA, 2020.
39. Heritage Foundation Methodology. Available online: https://www.heritage.org/index/pdf/2020/book/methodology.pdf (accessed on 8 October 2021).
40. ILO. *Employment Protection Legislation: Summary Indicators in the Area of Terminating Regular Contracts (Individual Dismissals)*; ILO: Geneva, Switzerland, 2015; ISBN 9789221294764.
41. Kässi, O.; Lehdonvirta, V. Online labour index: Measuring the online gig economy for policy and research. *Technol. Forecast. Soc. Chang.* **2018**, *137*, 241–248. [CrossRef]
42. Auer, P. Protected Mobility for Employment and Decent Work: Labour Market Security in a Globalized World. *J. Ind. Relat.* **2006**, *48*, 21–40. [CrossRef]

43. Bhattacharjea, A. Labour market flexibility in Indian industry. A critical survey of the literature. *Cent. Dev. Econ. Delhi Sch. Econ. Work. Pap.* **2019**, *160*, 197–217. [CrossRef]
44. Aleksynska, M.; Cazes, S. Composite indicators of labour market regulations in a comparative perspective. *IZA J. Labor Econ.* **2016**, *5*, 3. [CrossRef]
45. Cazes, S. Do Labour Market Institutions Matter in Transition Economies? An Analysis of Labour Market Flexibility in the Late Nineties. *SSRN Electron. J.* **2005**. [CrossRef]
46. OECD Tax Wedge (Indicator). Available online: https://www.oecd-ilibrary.org/taxation/tax-wedge/indicator/english_cea9eba3-en (accessed on 8 October 2021).
47. OECD Trade Unions: Trade Union Density (Edition 2016). Available online: https://www.oecd-ilibrary.org/employment/data/trade-unions/trade-unions-trade-union-density-edition-2016_fbf99961-en (accessed on 8 October 2021).
48. OECD. *Negotiating Our Way up. Collective Bargaining in a Changing Word*; OECD: Paris, France, 2019.
49. OECD Collective Bargaining Coverage. Available online: https://www.oecd.org/employment/collective-bargaining.htm (accessed on 10 October 2021).
50. Oliveira, P.; Forte, R. Labour market flexibility and FDI attraction: A macroeconomic analysis. *Panoeconomicus* **2018**, *68*, 267–291. [CrossRef]
51. Hwang, C.-L.; Yoon, K. Methods for Multiple Attribute Decision Making. In *Multiple Attribute Decision Making*; Springer: Berlin/Heidelberg, Germany, 1981.
52. Hellwig, Z. Zastosowanie metody taksonomicznej do typologicznego podziału krajów ze względu na poziom ich rozwoju oraz zasoby i strukturę wykwalifikowanych kadr. *Prz. Stat.* **1968**, *4*, 307–327.
53. Behzadian, M.; Khanmohammadi Otaghsara, S.; Yazdani, M.; Ignatius, J. A state-of the-art survey of TOPSIS applications. *Expert Syst. Appl.* **2012**, *39*, 13051–13069. [CrossRef]
54. Rudnik, K.; Kacprzak, D. Rozmyta Metoda TOPSIS Wykorzystująca Skierowane Liczby Rozmyte. *XVIII Konf. Innow. Zarz. Inż. Prod.* **2015**, 958–968. Available online: http://www.ptzp.org.pl/files/konferencje/kzz/artyk_pdf_2015/T1/t1_0958.pdf (accessed on 8 October 2021).
55. Ladorucki, G.; Wolski, W. Ewaluacja dostawców w procesie logistycznym przedsiębiorstwa metodą fTOPSIS. *Stud. Proc. Pol. Assoc. Knowl. Manag.* **2018**, *88*, 52–62.
56. Zyoud, S.H.; Fuchs-Hanusch, D. A bibliometric-based survey on AHP and TOPSIS techniques. *Expert Syst. Appl.* **2017**, *78*, 158–181. [CrossRef]
57. Chen, K.H.; Liao, C.N.; Wu, L.C. A selection model to logistic centers based on TOPSIS and MCGP methods: The case of airline industry. *J. Appl. Math.* **2014**, *2014*, 470128. [CrossRef]
58. Shahanaghi, K.; Yazdian, S. Vendor selection using a new fuzzy group TOPSIS approach. *J. Uncertain Syst.* **2009**, *3*, 221–231.
59. Freeman, J.; Chen, T. Green supplier selection using an AHP-Entropy-TOPSIS framework. *Supply Chain Manag.* **2015**, *20*, 327–340. [CrossRef]
60. Boran, F.E.; Genç, S.; Kurt, M.; Akay, D. A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Syst. Appl.* **2009**, *36*, 11363–11368. [CrossRef]
61. Chu, T.C.; Lin, Y.C. A fuzzy TOPSIS method for robot selection. *Int. J. Adv. Manuf. Technol.* **2003**, *21*, 284–290. [CrossRef]
62. Dağdeviren, M.; Yavuz, S.; Kilinç, N. Weapon selection using the AHP and TOPSIS methods under fuzzy environment. *Expert Syst. Appl.* **2009**, *36*, 8143–8151. [CrossRef]
63. Mahmoodzadeh, S.; Shahrabi, J.; Zaeri, M.; Pariazar, M. Project selection by using fuzzy AHP and TOPSIS technique. *Int. J. Hum. Soc. Sci.* **2007**, *1*, 270–275.
64. Dmytrów, K. Wpływ wag w metodach TOPSIS i TMAL na czas kompletacji produktów—Analiza symulacyjna. *Stud. Pr. Wydz. Nauk Ekon. Zarz. US. Metod. Ilościowe Ekon.* **2018**, *54*, 103–112. [CrossRef]
65. Roszkowska, E. Analiza procesu negocjacji z wykorzystaniem procedury TOPSIS. Studia ekonomiczne. *Stud. Ekon. Uniw. Ekon. Katow.* **2013**, *138*, 95–108.
66. Wachowicz, T. Metody i narzędzia wspomagania fazy prenegocjacyjnej. *Decyzje* **2010**, *14*, 55–84.
67. Sun, C.C.; Lin, G.T.R. Using fuzzy TOPSIS method for evaluating the competitive advantages of shopping websites. *Expert Syst. Appl.* **2009**, *36*, 11764–11771. [CrossRef]
68. Büyüközkan, G.; Ifi, G. A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Syst. Appl.* **2012**, *39*, 3000–3011. [CrossRef]
69. Yu, X.; Guo, S.; Guo, J.; Huang, X. Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS. *Expert Syst. Appl.* **2011**, *38*, 3550–3557. [CrossRef]
70. Kabir, G.; Hasin, M.A.A. Comparative Analysis of TOPSIS and Fuzzy TOPSIS for the Evaluation of Travel Website Service Quality. *Int. J. Qual. Res.* **2012**, *6*, 169–185.
71. Kelemenis, A.; Askounis, D. A new TOPSIS-based multi-criteria approach to personnel selection. *Expert Syst. Appl.* **2010**, *37*, 4999–5008. [CrossRef]
72. Shekari, G.A.; Khayat Moghadam, S.; Hakimzadeh, A.; Salahshour, S.; Keifi, A.H. Ranking factors affecting the productivity of human resources using MADM techniques. *J. Soft Comput. Appl.* **2012**, *2012*, 9. [CrossRef]
73. Safari, H.; Cruz-Machado, V.; Zadeh Sarraf, A.; Maleki, M. Multidimensional personnel selection through combination of TOPSIS and Hungary assignment algorithm. *Manag. Prod. Eng. Rev.* **2014**, *5*, 42–50. [CrossRef]

74. Mammadova, M.H.; Jabrayilova, Z.G. Decision-making support in human resource management based on multi-objective optimization. *TWMS J. Pure Appl. Math* **2018**, *9*, 52–72.
75. Bilbao-Terol, A.; Arenas-Parra, M.; Cañal-Fernández, V.; Antomil-Ibias, J. Using TOPSIS for assessing the sustainability of government bond funds. *Omega* **2014**, *49*, 1–17. [CrossRef]
76. Ginting, G.; Fadlina, F.; Aan, M.; Rahim, R.; Siahaan, A.P.U. Technical Approach of TOPSIS in Decision Making. *Int. J. Recent Trends Eng. Res.* **2017**, *3*, 58–64. [CrossRef]
77. Trstenjak, B.; Kavran, A.K.; Bujan, I. Evaluation of Croatian Development Strategies Using SWOT Analyses with Fuzzy TOPSIS Method and K-Means Methods. *J. Econ. Bus. Manag.* **2015**, *3*, 687–693. [CrossRef]
78. Awasthi, A.; Chauhan, S.S.; Omrani, H.; Panahi, A. A hybrid approach based on SERVQUAL and fuzzy TOPSIS for evaluating transportation service quality. *Comput. Ind. Eng.* **2011**, *61*, 637–646. [CrossRef]
79. Krohling, R.A.; Campanharo, V.C. Fuzzy TOPSIS for group decision making: A case study for accidents with oil spill in the sea. *Expert Syst. Appl.* **2011**, *38*, 4190–4197. [CrossRef]
80. Lai, Y.J.; Liu, T.Y.; Hwang, C.L. TOPSIS for MODM. *Eur. J. Oper. Res.* **1994**, *76*, 486–500. [CrossRef]
81. Yeh, C.H. A Problem-based Selection of Multi-attribute Decision-making Methods. *Int. Trans. Oper. Res.* **2002**, *9*, 169–181. [CrossRef]
82. Trzaskalik, T. Wielokryterialne wspomaganie decyzji: Przegląd metod i zastosowań. *Zesz. Nauk. Politech. Śl. Organ. Zarz.* **2014**, *74*, 239–263.
83. Komlan, G. Integrating AHP-TOPSIS Approach on Prioritizing Self-Service Technology (SST) Decision Making in Financial Institution (TOGO). *Br. J. Math. Comput. Sci.* **2016**, *16*, 1–22. [CrossRef]
84. Szarafinska, M.; Fabisiak, L. Analiza porównawcza metod wielokryterialnych w ocenie audiencji serwisów internetowych. *Metod. Ilościowe Bad. Ekon. Szk. Główna Gospod. Wiej.* **2010**, *11*, 232–241.
85. García-Cascales, M.S.; Lamata, M.T. On rank reversal and TOPSIS method. *Math. Comput. Model.* **2012**, *56*, 123–132. [CrossRef]
86. Li, X.; Wang, K.; Liuz, L.; Xin, J.; Yang, H.; Gao, C. Application of the entropy weight and TOPSIS method in safety evaluation of coal mines. *Procedia Eng.* **2011**, *26*, 2085–2091. [CrossRef]
87. Wu, C.S.; Lin, C.T.; Lee, C. Optimal marketing strategy: A decision-making with ANP and TOPSIS. *Int. J. Prod. Econ.* **2010**, *127*, 190–196. [CrossRef]
88. Ezhilarasan, N.; Vijayalakshmi, C. Optimization of Fuzzy programming with TOPSIS Algorithm. *Procedia Comput. Sci.* **2020**, *172*, 473–479. [CrossRef]
89. Ban, A.I.; Ban, O.I.; Bogdan, V.; Sabau Popa, D.C.; Tuse, D. Performance evaluation model of Romanian manufacturing listed companies by fuzzy AHP and TOPSIS. *Technol. Econ. Dev. Econ.* **2020**, *26*, 808–836. [CrossRef]
90. Bąk, A. Zastosowanie metod wielowymiarowej analizy porównawczej do oceny stanu środowiska w województwie dolnośląskim. *Wiad. Stat.* **2018**, *63*, 7–20.
91. Luczak, A.; Just, M. The positional MEF-TOPSIS method for the assessment of complex economic phenomena in territorial units. *Stat. Transit.* **2020**, *21*, 157–172. [CrossRef]
92. Kopczuk, A. *Benchmarking Powiatów i Miast Powiatowych (Gmin Miejskich) w Województwie Podlaskim—Zróżnicowanie Przedsiębiorczości i Dynamiki Rozwoju Gospodarczego*; Urząd Marszałkowski Woj: Białystok, Poland, 2015.
93. Łuczak, A.; Wysocki, F. Zastosowanie uogólnionej miary odległości GDM oraz metody TOPSIS do oceny poziomu rozwoju społeczno-gospodarczego powiatów województwa wielkopolskiego. *Prz. Stat.* **2012**, *59*, 298–311.
94. Roszkowska, E.; Piotrowska, E. Analiza zróżnicowania województw Polski w aspekcie kształtowania się gospodarki opartej na wiedzy. In *W Kierunku Zrównoważonej Gospodarki Opartej na Wiedzy w Polsce*; Sochaczewski, P., Ed.; Wyższa Szkoła Ekonomiczna w Białymstoku: Białystok, Poland, 2011; pp. 12–51.
95. Ren, L.; Zhang, Y.; Wang, Y.; Sun, Z. Comparative analysis of a novel M-TOPSIS method and TOPSIS. *Appl. Math. Res. eXpress* **2007**, *2007*, abm005. [CrossRef]
96. Marti, L.; Puertas, R. European countries' vulnerability to COVID-19: Multicriteria decision-making techniques. *Econ. Res. Istraz.* **2021**. [CrossRef]
97. Ertman, A. Zróżnicowanie elastyczności rynków pracy w wybranych krajach europejskich oraz USA w świetle metody TOPSIS. *Oecon. Copernic.* **2011**, *3*, 43–64. [CrossRef]
98. Jadamus-Hacura, M.; Melich-Iwanek, K. Elastyczność współczesnych rynków pracy. *Stud. Ekon.* **2015**, *220*, 36–57.
99. OECD Glossary of Statistical Terms. EU15. Available online: https://stats.oecd.org/glossary/detail.asp?ID=6805 (accessed on 10 October 2021).
100. European Commission Eurostat. *New Techniques and Technologies for Statistics II. Proceedings of the Second Bonn Seminar*; IOS Press: Amsterdam, The Netherlands, 1997.
101. OECD Tax Wedge. Available online: https://data.oecd.org/tax/tax-wedge.htm (accessed on 12 October 2021).
102. OECD Trade Union. Available online: https://stats.oecd.org/ (accessed on 10 October 2021).
103. OECD Unemployment Rate. Available online: https://www.oecd-ilibrary.org/employment/unemployment-rate/indicator/english_997c8750-en (accessed on 9 October 2021).
104. OECD Temporary Employment. Available online: https://www.oecd-ilibrary.org/employment/temporary-employment/indicator/english_75589b8a-en (accessed on 10 October 2021).

105. OECD Part-Time Employment Rate. Available online: https://www.oecd-ilibrary.org/employment/part-time-employment-rate/indicator/english_f2ad596c-en (accessed on 10 October 2021).
106. OECD Employment Rate by Age Group. Available online: https://www.oecd-ilibrary.org/employment/employment-rate-by-age-group/indicator/english_084f32c7-en (accessed on 10 October 2021).
107. Siek, E. Elastyczność rynków pracy a bezrobocie w krajach Unii Europejskiej w okresie kryzysu. *Gospod. Prakt. Teor.* **2012**, *2*, 115–127.
108. European Commission Employment, Social Affairs & Inclusion. Available online: https://ec.europa.eu/social/home.jsp (accessed on 10 October 2021).
109. Yang, Z. Tax reform, fiscal decentralization, and regional economic growth: New evidence from China. *Econ. Model.* **2016**, *59*, 520–528. [CrossRef]
110. Poniatowicz, M. Determinanty autonomii dochodowej samorządu terytorialnego w Polsce. *Nauk. Finans.* **2015**, *1*, 11–30. [CrossRef]
111. Gonzalez, B. *Globalization: Economic, Political and Social Issues*; Nova Science Publishers, Inc.: New York, NY, USA, 2016; ISBN 1634854535.
112. Lall, S.; Narula, R. Foreign direct investment and its role in economic development: Do we need a new agenda? *Eur. J. Dev. Res.* **2004**, *16*, 447–464. [CrossRef]
113. Driffield, N.; Taylor, K. FDI and the labour market: A review of the evidence and policy implications. *Oxf. Rev. Econ. Policy* **2000**, *16*, 90–103. [CrossRef]
114. Almeida, F.; Santos, J.D. The effects of COVID-19 on job security and unemployment in Portugal. *Int. J. Sociol. Soc. Policy* **2020**, *40*, 995–1003. [CrossRef]

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Identification of Villages' Development Types Using a Comprehensive Natural–Socioeconomic Framework

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Abstract: The establishment of a comprehensive framework to identify village development types is crucial to formulate plans for rural development and promote rural revitalization. This study proposed a natural–socioeconomic framework to identify the types of villages based on field survey, statistical data, and multi-source remote sensing images. The framework was constructed by combining the two-dimensional natural suitability/restriction evaluation and the four-dimensional socioeconomic development level evaluation. Then, the modified multiplication-weighted summation method and the coupling coordination degree algorithm were employed to identify the villages' development types. A total of 774 villages of the Laiyang County, eastern China were used as the study areas to examine the framework. The results demonstrated the following. (1) There were 243,318 and 151 villages with high, moderate, low natural suitability, and 62 villages with natural restrictions; and 158,366 and 250 villages with high, moderate, and low economic development level, respectively. The distribution characteristic of natural evaluation was "high in the southwest and low in the northeast", and the socioeconomic development level was generally centered on the urban area, which presented a "high–medium–low" circle-layer distribution structure. (2) There were 247 villages with high-level coupling coordination, 464 villages with intermediate coupling coordination, 1 village with low-level coupling coordination, and 62 villages with disordered coupling. (3) Based on the coupling coordination evaluation results, villages in the study area were grouped into five types: urbanization development (31%), construction development (16%), agglomeration linkage development (27%), decrease and improvement development (18%), and relocation and integration development (8%). The framework of villages' development types identification established in this study can enrich the theory of rural geography, and the applied research results can provide a basis for rural revitalization and development planning.

Keywords: comprehensive natural–socioeconomic framework; multi-source data; natural suitability/restriction; socioeconomic development level; coupling and coordination

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1. Introduction

The rural village is a natural and social complex formed over time that couples the ecological environment and socioeconomic systems [1]. Sustainable development is determined by a set of socioeconomic and natural environmental factors for rural areas. Different countries and regions have different policies for rural development due to different levels of development. In order to improve the rural living environment and the living standard of rural residents as well as reduce the gap between urban and rural development, many countries developed sustainable development strategies [2] and programs using different methodological approaches.

In China, rural villages are experiencing prominent population loss and socioeconomic recession, especially those with harsh natural environments and remote locations [3]. Imbalanced development between urban and rural areas and inadequate rural development have become two major societal concerns. The Chinese government puts forward

the strategy of rural revitalization and proposes that rural village development should be promoted according to the development status, location conditions, and resource endowments of different villages in accordance with the law and evolutionary trends of village development [4].

Therefore, from the comprehensive perspectives of the natural suitability and the level of socioeconomic development, it has become an important issue for China to implement the strategy of Rural Revitalization. Taking Laiyang County of Shandong Province as an example, based on field investigation, statistical data, and multi-source remote sensing images, this paper combines two-dimensional natural suitability/restriction with a four-dimensional socioeconomic development level, constructs a comprehensive natural–socioeconomic framework, identifies and analyzes the development types of villages, and puts forward constructive development suggestions, Thus, it enriches the theoretical framework and system of village classification development, and it also provides a scientific basis for making regional village development decisions.

The structure of this paper is as follows. Section 2 provides a literature review and proposes the research direction of this study. Section 3 presents the construction of the comprehensive natural–socioeconomic framework, which forms the theoretical support for this study. Section 4 introduces the study area, data sources, research methods, and processing. Section 5 presents an analysis of the results of the natural suitability/restriction evaluation, socioeconomic development level evaluation, coupling coordination between natural suitability and socioeconomic development level, and villages' development types identification, and it also discusses the theoretical contributions and future prospects of this study. Section 6 presents the conclusions.

2. Literature Review

Recent studies on rural areas mainly focus on the neo-endogenous rural development [5], social innovation in rural governance [6], critical drivers for sustainable development in rural areas [7], the potential using efficiency of rural development [8], rural development and natural resource management [9], urban–rural development [10], rural sustainable development [11,12], rural revitalization [13,14], rural transformation [15], rural tourism [16–18], wisdom [19,20], and beautiful village construction [21]. The research area is distributed in different countries and regions, including Europe, Russia, and post-Soviet countries, Italy, Korea, America, and China. Different characteristics of the natural environment and regional socioeconomic conditions lead to great differences in the development of villages. Therefore, the development types of villages should be identified so as to detect the feasible development and revitalization paths to better guide the direction of village development. Research has been conducted on the identification of villages' development types. For instance, the conditions of village relocation and consolidation were identified by constructing the suitability evaluation indexes system from three aspects (landscape index, topographical conditions, land utilization situation) [22]. In addition, some studies focused on the evaluation of villages' development levels [23], e.g., the village development evaluation indexes system was constructed from three aspects of production, life, and ecological function; or from four dimensions of living resources, industrial base, regional transportation, and cultural ecological environment, to detect the types of villages [24,25].

Most of the rural economic indicators involved in the evaluation indexes system are based on the conventional economic statistical indicators, such as the per capita disposable income of residents [26], economic density, total agricultural output value [27], per capita total output value of agriculture [28], ratio of non-agricultural output value [29], and development level of village collective economy [30]. Since the 1990s, the nighttime light remote sensing data were gradually used to objectively reflect the level of social and economic development of a region [31]. Especially, the Luojia1-01 image can reflect social and economic development in finer spatial resolution, which is one of the most professional types of nighttime light remote sensing data [32], and it was used to detect the development of constructed areas, e.g., county-level regions in Hubei, Hunan, and Jiangxi [33]. However,

the application of Luojia1-01 is temporally concentrated in urban areas [34], involving population spatialization [35], population distribution [36], economic index prediction [37], etc. The application of nighttime light remote sensing images in rural areas remains to be an emergent task. Therefore, it is indispensable to explore the application of Luojia1-01 nighttime light images in rural socioeconomic development evaluation.

Studies on rural development employed the suitability or development levels of a single aspect to identify the villages' development types. However, the village is the coupling of natural environment and social economy; a clear and systematic framework combining natural and socioeconomic factors is indispensable to the identification of the villages' development types. According to the coupling and coordinating relationship between the natural environment and social economy, we should build a comprehensive framework and divide the development types of rural villages. The coupling coordination degree model is a model originating from physics, which is used to evaluate the coupling coordination relationship between different systems. It is currently a reference for measurements by different systems or system coupling coordination between internal elements. However, the existing studies were merely limited to new urbanization, rural settlement layout [38–40], etc., which is difficult to be extended to the identification of villages' development types. Hence, it is important to strengthen the direction of study that couples the suitability and development of village development types. Furthermore, it is the uppermost priority of the current research to explore the implementation path suitable for China's rural development.

Thus, this study strived to proposed a comprehensive natural–socioeconomic framework of villages' development types with natural–socioeconomic factors and multi-source data. The study was conducted and examined in the villages of Laiyang County, eastern China. Comprehensive consideration of natural suitability and socioeconomic development, the modified multiplication-weighted summation method, and the coupling coordination degree model were used to establish the comprehensive natural–socioeconomic framework, which was used to identify the villages' development types scientifically and then put forward rural revitalization suggestions. The study was expected to provide a reference for promoting the rural revitalization and village planning.

3. Comprehensive Natural–Socioeconomic Framework

The formation and development of rural villages are influenced by the natural environment and socioeconomic systems. Rural development and revitalization should be based on the natural environmental conditions of villages, which provide basic conditions for the development of villages. Meanwhile, such villages also have more populations, higher incomes, and better infrastructure. If the natural conditions are not adequate for development (excessive slopes in the terrain or being prone to geological disasters), the villages will be restricted and will gradually decline or even die out. Therefore, there is usually a certain coupling between the natural environmental conditions of villages and their socioeconomic development. In addition, due to the differences in transportation, economic input, and management, rural socioeconomic development levels are different. The conventional economic development factors are not sufficient to reflect the level of economic development. As the nighttime light images can reflect the regional economic level objectively, they should be included to construct the framework to identify the type of rural village development.

The comprehensive natural–socioeconomic framework (Figure 1) was constructed as the following steps. Firstly, on account of the natural environment conditions, factors such as slope, altitude, water resources, geological hazards, and ecological functional areas were selected; the modified multiplication-weighted summation model was used to evaluate the suitability and restriction of rural development. When a natural factor was worse than a certain value and unsuitable for human habitation, it was determined as a restricted development area. In other regions, the suitability level of village development was evaluated according to the levels of natural factors affecting human productivity and

life. Secondly, from the perspective of socioeconomics, the high-grade road, historical and cultural resources, total population, collective income, average light density at night, education, and medical treatment were selected from four dimensions of traffic location, resource endowment, cluster scale, and basic facilities, to evaluate the socioeconomic development of villages. Finally, the coupling coordination degree model was employed to evaluate the coupling coordination degree of rural natural suitability and socioeconomic development. Based on the evaluation results of coupling coordination degree, natural suitability, and socioeconomic development, the village development types were assigned, and then differentiated suggestions for rural development and revitalization were put forward.

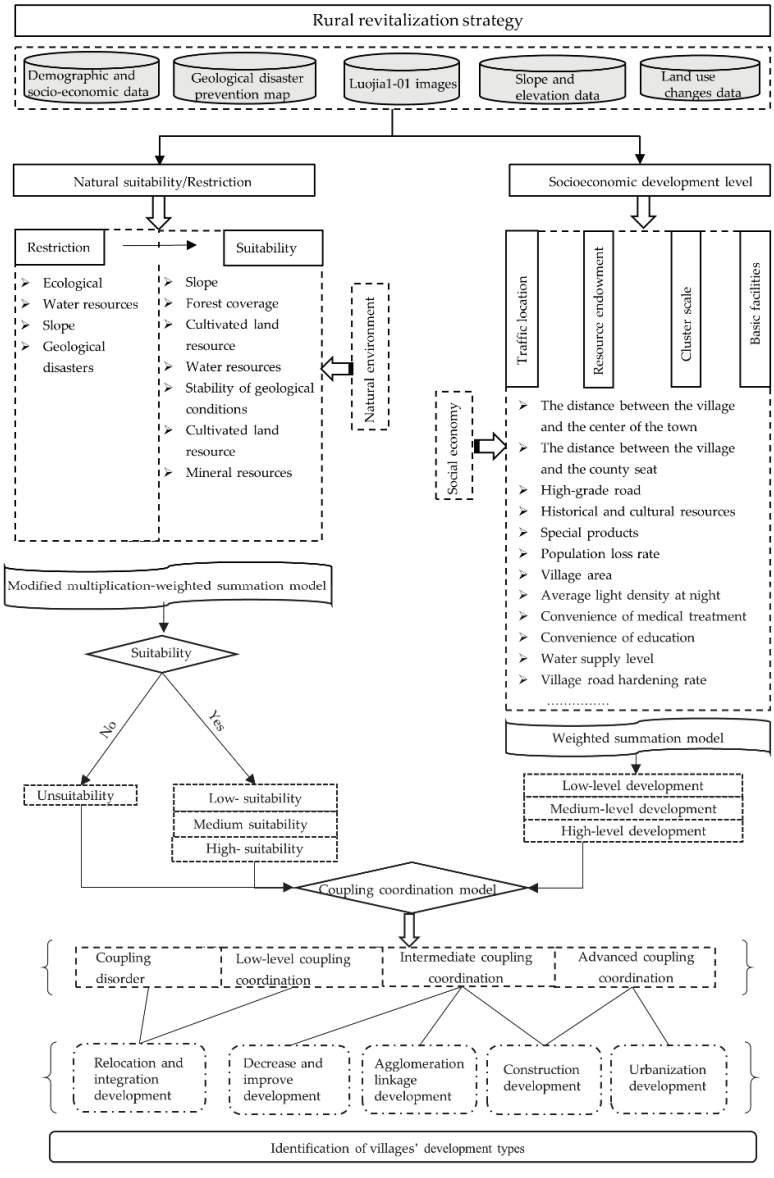


Figure 1. Comprehensive natural–socioeconomic framework.

4. Methodology and Data Source

4.1. Study Area

Laiyang County (120°31′06″−120°59′12″ E, 36°34′25″−37°09′46″ N) is located in the east of Shandong province, eastern China (Figure 2). The study area contains 18 towns (784 villages) with a permanent population of 872,000 and an area of 1732 km^2, in which the cultivated land area is 830 km^2. It is a low hilly area with a maximum elevation of 375 m. The terrain slopes from north to south, among which 68.7% is low-mountainous hilly and 31.3% is flat. It has a temperate monsoon sub humid climate, adequate light, and four distinct seasons. The territory is rich in mineral resources, mainly minerals, among which the reserves of bentonite and zeolite rank second in the province. It is known as the hometown of Chinese pears, Chinese dinosaurs, calligraphy, and peanut oil. Since ten villages are urban villages, they were not within the scope of this study. Therefore, 774 villages were finally identified as the research objects.

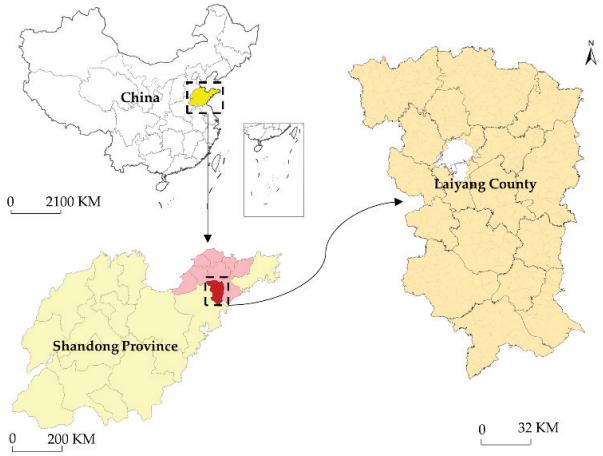


Figure 2. Location of the study area.

4.2. Data Source

The data sources include: (1) Laojia1-01 nighttime light images, which were from Hubei data and an application network of a high-resolution earth observation system and processed by Envi5.3 and ArcGIS 10.7; (2) remote sensing images of Laiyang County's geographical national conditions survey 5–6 in 2019, land-use change data in 2018 and a geological disaster prevention map of Laiyang County, which were obtained from the Laiyang Natural Resources and Planning Bureau; (3) demographic and socioeconomic data, which were from the Laiyang Bureau of Statistics, the Statistical Yearbook of Laiyang County, Social, and Economic Statistical Bulletin of Laiyang County and field questionnaire; (4) slope and elevation data were mainly derived from the geospatial data cloud of the Chinese Academy of Sciences.

4.3. Evaluation of Natural Suitability/Restriction

4.3.1. Selection of Evaluation Indexes

Villages are generally developed and formed in regions with flat terrain, rich resources, good geology, and ecological security. Within a certain range, the smaller the slope and elevation, the more convenient are production and life, and thus, it is more conducive to the formation and development of the village. The forest land coverage rate reflects the ecological quality, and the higher the forest land coverage rate, the better the ecological environment quality. Natural resources such as water, arable land, and minerals form the material basis of rural development. The richer the natural resources, the greater the potential for rural development. Good geological conditions and low risks for disasters

are conducive to long-term rural development. However, villages are not suited to areas with bad natural conditions, such as excessive slopes, excessive elevation, proneness to geological disasters, being located in ecological protection areas, being too close to water, and being prone to floods. Therefore, these villages' development should be restricted.

Laiyang County is located on low-mountain and hilly land with a peak altitude of 375 m. It is rich in arable land, water, and mineral resources, but their distribution is uneven. Considering the natural suitability, restrictions, and natural environment conditions, seven evaluation indexes, i.e., the slope, altitude, geological conditions, forest coverage, cultivated land resources, distance from river/reservoirs and mineral resources were selected to evaluate the natural suitability/restriction of villages, and five indexes (important ecological areas, distance from water, altitude [41], slope, and risk of geological disaster) [42] were selected to evaluate restrictions for village development (Table 1).

Table 1. Indexes and weights of natural suitability/restriction evaluation in the study area.

Category	Indicators	Weight	Description	Attribute [1]
Restrictive	Ecological area	-	(whether it was ecological important functional area) Yes = 0, No = 1	-
	Water resources	-	(whether the distance from the river reservoir was less than 500 m) Yes = 0, No = 1	-
	Slope	-	(whether the slope was greater than 25°) Yes = 0, No = 1	-
	Geological disasters	-	(whether geological disasters were highly prone to occurrence) Yes = 0, No = 1	-
Suitability	Slope	0.25	<2° = 4, 2°–6° = 3, 6°–15° = 2, 15°–25° = 1	+
	Elevation	0.25	Classification by elevation value	−
	Forest coverage	0.08	Forestland coverage rate = forestland area/total village area	+
	Cultivated land resource	0.08	Ratio of cultivated land = total area of cultivated land in village	+
	Water resources	0.13	The distance from the river reservoir was 500–1000 m = 4, 1000–1500 m = 3, 1500–2000 m = 2, > 2000 m = 1	+
	Geological conditions	0.13	No risk = 3, low risk = 2, medium risk = 1	+
	Mineral resources	0.08	Potassium feldspar and iron ore = 4, soil ore = 3, rock brick and stone = 2, none = 1	+

[1] "+" A positive index, indicating that the higher the score, the better the index; "−" A negative index, indicating that the lower the score, the better the index.

4.3.2. Quantification of Evaluation Indexes

According to the requirements of village development based on natural environment conditions, the restrictions and suitability factors were quantified by referring to relevant standards and literature [43]. First, the restrictive factor was quantified, and the score of the restrictive factor was set to 0 or 1. If a limiting factor reached an extreme value and restricted the village's construction, it was assigned 0, and the area was directly designated as an unsuitable area. An area below the extremum value was set as 1; it then continued to participate in the suitability evaluation. According to the influences of suitability factors on village construction and rural development, considering the reality of Laiyang County, the suitability factors were graded and assigned, and the extreme value method was adopted to conduct standardization treatment. The relative importance of each suitability factor on village construction and rural development was compared, and the weight of each suitability index was determined by analytic hierarchy process (AHP). A total of 15 experts, including professors and experts in land use, urban and rural planning land planning, land assessment and resource remote sensing, as well as representatives of natural resources bureau, planning institute, and other relevant units, were invited to score the indicators. Based on the scoring of all experts, the judgment matrix is constructed to make the weight

quantitative on the basis of qualitative data, and the result is more objective. The indexes and weights for natural suitability evaluation are shown in Table 1.

4.3.3. Construction of Modified Multiplication-Weighted Summation Evaluation Model

This study took the village as the unit and constructed a modified multiplication-weighted summation evaluation model to evaluate suitability/restriction. It includes the following two parts:

Firstly, we used the series multiplication model [44] to evaluate restriction. As long as the index value of one factor exceeded the limit value, a village was classified as an unsuitable development zone and a restricted construction zone. The specific formula is shown in Equation (1), which was shown below:

$$S_x = \prod_{k=1}^{m} A_{kx} \quad (1)$$

where S_x is the restriction index of a village x; m is the number of limiting value evaluation factors; k is the order of limiting value factor; and A_{kx} is the score of the kth limit value factor of a village x.

For the other villages, the natural suitability index was calculated by the weighted summation model [45] to evaluate their natural suitability. The calculation formula is shown in Equation (2), as follows:

$$S_y = \sum_{i=1}^{j} B_{iy} \times b_i \quad (2)$$

where S_y is the suitability index of a village y, j is the number of suitability evaluation factors; i is the order of suitability factor; B_{iy} is the score of the ith suitability factor of a village y; and b_i is the weight of the ith suitability factor.

4.4. Evaluation of Socioeconomic Development

4.4.1. Selection of Evaluation Indexes

The socioeconomic development level of villages is mainly reflected in traffic location, resource endowment, cluster scale, and basic facilities. Good traffic location facilitates the flow of people and resources. The higher the grade of road, the easier it is to travel, and the more conducive to the development of a village. The closer a village is to a town, the easier it is to be driven by its development. The endowment of social resources, such as historical cultural resources and specialty products, is formed by long-term development, which is not only a sign of the level of rural development but also an advantage for future development. The scale of village agglomeration, including the population, income level, and village size, is a sign of the level of rural development. The larger the population, the higher the income, the brighter the nightlight, and the larger the village scale, the higher the level of village development. Under the current trend of rural population outflow, excessive population outflow affects the development of villages. Village infrastructure construction includes educational conditions, medical conditions, hardened roads, water supply, gas supply, etc., which are all reflections of rural development and the quality of production and life. The more perfect the infrastructure, the more comfortable people's lives will be.

The study area has high-speed railway and various levels of highways. The travel conditions and the radiation effect of cities and towns also differ among different villages with different road grades and distances to cities and towns [46]. Laiyang pear, Wu Long calligraphy, and other cultural resources and specialty products are renowned at home and abroad; part of the villages was a historical and cultural village, dinosaur fossil village, and other specialty villages. Village cluster scale, such as population [47], economy, and land agglomeration [48], is different. The study area attaches great importance to rural

construction and has relatively good infrastructure [49], but there are differences among villages. Hence, 14 indicators were selected from four dimensions, including traffic location, resource endowment, cluster scale, and basic facilities, to construct the evaluation indexes system of rural socioeconomic development in the study area, as shown in Table 2.

Table 2. Weights of socioeconomic development indicators for Laiyang County.

Criterion Layer	Weight	Indexes Layer	Weight	Calculation Method and Description [1]	Attribute [2]
Traffic location	0.23	The distance between the village and the center of the town	0.17	Calculated using the NEAR tool in ArcGIS	−
		The distance between the village and the county seat	0.29	Calculated using the NEAR tool in ArcGIS	−
		High-grade road	0.54	National road = 4; Provincial road = 3; County and township road = 2; Others = 1	+
Resources endowment	0.12	Historical and cultural resources	0.50	(Whether it is a folk village) Yes = 1, No = 0	+
		Special products	0.50	(Do they have any special products?) Yes = 1, No = 0	+
Cluster scale	0.42	Population	0.30	Permanent population	+
		Population loss rate	0.30	Population loss rate = (registered residence population—resident total population)/registered residence population	−
		Economic situation	0.32	Collective income	+
				Average light density at night	+
		Village area	0.08	Village area	+
Basic facilities	0.23	Convenience of medical treatment	0.16	Distance between the nearest hospital and the village committee	−
				(whether there is a community health service) Yes = 1, No = 0	+
		Convenience of education	0.16	(whether there is kindergarten) Yes = 1, No = 0	+
				Distance between the nearest primary school and the village committee	−
				The nearest junior high school and this village (residence) committee distance	−
		Gas supply level	0.08	(Whether pipeline gas is connected) Yes = 1, No = 0	+
		Water supply level	0.26	Tap water = 1, bottled water = 2, purified water = 3, mineral water = 4, water purifier = 5	−
		Village road hardening rate	0.34	Village road hardening rate = road hardening length/total road length	+

[1] Economic situation, "collective income" is as important as "average light density at night"; Convenience of medical treatment, "distance between the nearest hospital and the village committee" is as important as "whether there is a community health service"; Convenience of education, "whether there is kindergarten", "distance between the nearest primary school and the village committee", and "the nearest junior high school and this village (residence) committee distance" are equally important. [2] "−" A negative indexes, indicating that the lower the score, the better the indexes; "+" A positive indexes, indicating that the higher the score, the better the indexes.

4.4.2. Quantification of Evaluation Indicator

Considering the impacts of evaluation indicators on rural socioeconomic development, combined with the reality of the study area, the indexes values were calculated or assigned directly, and the extreme value method was adopted to standardize the indicators. Distance indexes include the quantification of the distance from a given village to the nearest town center and to the county seat. They were calculated using the near tool in ArcGIS. AHP was used to determine the weights of indicators. The quantification, weight, and attributes of each indicator are shown in Table 2.

4.4.3. Construction of a Weighted Summation Evaluation Model

The weighted summation model [50] was constructed to calculate the socioeconomic development indexes of villages. The formula is shown in Equation (3).

$$F_y = \sum_{i=1}^{m} (J_{ny} \times j_n) \tag{3}$$

where F_y is the socioeconomic development index of village y; m is the socioeconomic index number; J_{ny} is the nth standardized socioeconomic indicator value of village y; and j_n is the nth socioeconomic index weight.

4.5. Identification of Villages' Development Types

4.5.1. Construction of the Coupling Degree Model

Coupling refers to the phenomenon in which two or more systems or forms influence each other and even unite through interaction. A coupling degree model is an effective model to measure the synergistic relationship between two or more elements [51]. In this study, the coupling degree model is constructed to measure the coupling degree between the two systems of natural suitability and socioeconomic development level. The calculation is as follows:

$$C = 2 \times \left[\frac{S \times F}{(S+F)^2} \right]^{\frac{1}{2}} \tag{4}$$

where C is the coupling degree between natural suitability and socioeconomic development, $C \in [0, 1]$; S and F represent the natural suitability indexes and socioeconomic development level indexes, respectively. By referring to the existing classification standards [52] and combining them with the actual situation of the coupling degree in the study area, the coordination degree is divided into four levels: low-level, medium-level, superior-level, and high-level coupling. The classification standards are shown in Table 3.

Table 3. Coupling degree and coupling coordination degree division standard.

Coupling Degree *C*	Coordination Level	Coupling Coordination Degree *D*	Coordination Level
0.00–0.30	Low-level coupling	0.00–0.20	Coupling disorders
0.30–0.60	Medium-level coupling	0.20–0.40	Low-level coupling coordination
0.60–0.90	Superior-level coupling	0.40–0.60	Intermediate coupling coordination
0.90–1.00	High-level coupling	0.60–0.80	Advanced coupling coordination
-	-	0.80–1.00	Extreme coupled coordination

4.5.2. Construction of the Coupling Coordination Degree Model

Coupling coordination degree is used to judge the coupling and coordination status between systems and among various elements within the system. In this study, the coupling coordination degree model was constructed in order to judge whether the two systems of natural suitability and socioeconomic development level are consistent and the degree of interactive coupling between the two systems, so as to better identify the coupling

coordination relationship between them. The coordination index T and the coupling coordination degree D are calculated using Equations (5) and (6).

$$T = \mu \times S + v \times F \tag{5}$$

$$D = \sqrt{C \times T} \tag{6}$$

In Equations (5) and (6), T is the coordinated index of rural natural suitability and socioeconomic development, μ and v are undetermined coefficients, and $\mu + v = 1$. This study holds that rural natural suitability and socioeconomic development are equally important—$\mu = v = 0.5$. D is the coupling coordination degree of natural suitability and socioeconomic development. The higher the value of D, the better the coupling coordination of rural natural suitability and socioeconomic development. According to related studies [53,54] and according to the value of D, the region can be divided into five levels, namely coupling disorder, low-level coupling coordination, intermediate coupling coordination, advanced coupling coordination, and extreme coupling coordination, by using the uniform distribution method, as shown in Table 3.

5. Results and Discussions

5.1. Natural Suitability/Restriction Evaluation

The evaluation results using natural evaluation showed that different types of natural restrictions existed in 62 villages, and the natural suitability index S was 0, indicating that they were unsuitability areas (US). These villages are located in an ecological protection zone. They are close to the stream course or reservoir, and they are prone to flooding. They had large topographic variations or high risks for geological disasters. Therefore, they were considered US.

The natural suitability indexes S of the remaining 712 villages ranged from 0.23 to 0.83, and the commonly used natural break point method was used to categorize village suitability into three levels: high-suitability areas (HS), medium-suitability areas (MS), and low-suitability areas (LS). Analysis of the results found that the natural suitability of villages varied greatly, showing a gradually decreasing spatial distribution pattern from southwest to northeast, as shown in Figure 3. Among these villages, 243 villages in Chengxiang, Guliu, etc. were HS ($0.51 < S \leq 0.83$). These villages had flat terrain, low geological disaster risk, rich natural resources (such as water and arable land), high forest coverage rate, good ecological environment, and the suitability degree was high. Rural development and revitalization should prioritize these areas in the future. A total of 318 villages in Fenggezhuang, Jiangtuan towns were MS ($0.40 < S \leq 0.50$). Among them, Chadaokou, Xiyuquan, and other villages have relatively flat terrain, lesser risks of geological disaster, relatively abundant natural resources, good ecological environment quality, and high suitability. A total of 151 villages under the jurisdiction of towns such as north Jianggezhuang and Beimazhuang have steep slopes, complex terrain, geological hazards, a relative lack of water resources, little cultivated land, low ecological environment quality, or lower suitability. They had LS ($0.23 < S \leq 0.39$).

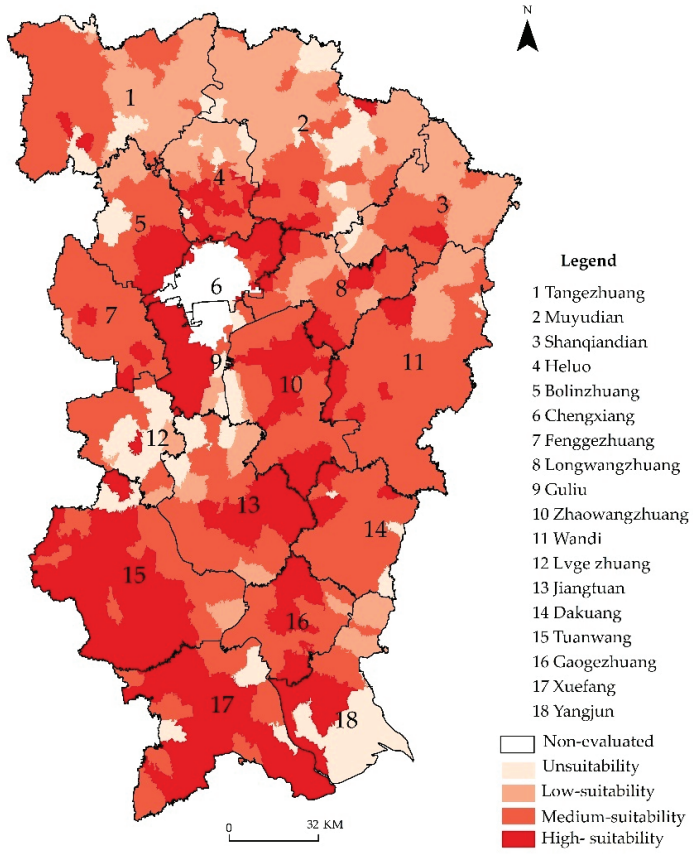


Figure 3. Evaluation results of village suitability in Laiyang City.

5.2. Socioeconomic Development Level Evaluation

The socioeconomic development index F of the villages in Laiyang County ranged from 0.12 to 0.52, and the values were grouped into three grades using the natural break point method: high-level development area (HD), medium-level development area (MD), and low-level development area (LD). It can be seen from Figure 4 that the level of rural socioeconomic development presents obvious spatial differences, and it presented a high–medium–low circle-layer distribution structure centered on the urban area. Statistical results found that there were 158 villages with HD ($0.29 < F \leq 0.52$), accounting for 20% of the evaluated villages. They are mainly distributed in Guliu, Chengxiang, and Jiangtuan towns. These villages have high-level traffic conditions, large areas, proximity to the urban area, expressways, more convenient village transportation, good infrastructure, clear resource advantages, and high overall development. A total of 366 villages occupied MD ($0.21 < F \leq 0.29$), accounting for 47% of the evaluated villages. They are mainly distributed in Bo Linzhuang, Heluo, Xuefang, Yangjun, and other towns. These villages had relatively good locations, relatively convenient external travel, some infrastructure, relatively abundant characteristic resources, high forest coverage rates, and relatively high development levels. Another 250 villages were LD ($F \leq 0.21$), accounting for 32% of the evaluated villages. They are concentrated in the northwest of Tangezhuang; the northeast of Wandi; and the southeast of Dakuang and other towns. These villages are far away from the city, and they have large slopes, imperfect infrastructure, the advantage of average scale (population, area, etc.), incomplete public facilities, and low levels of overall development.

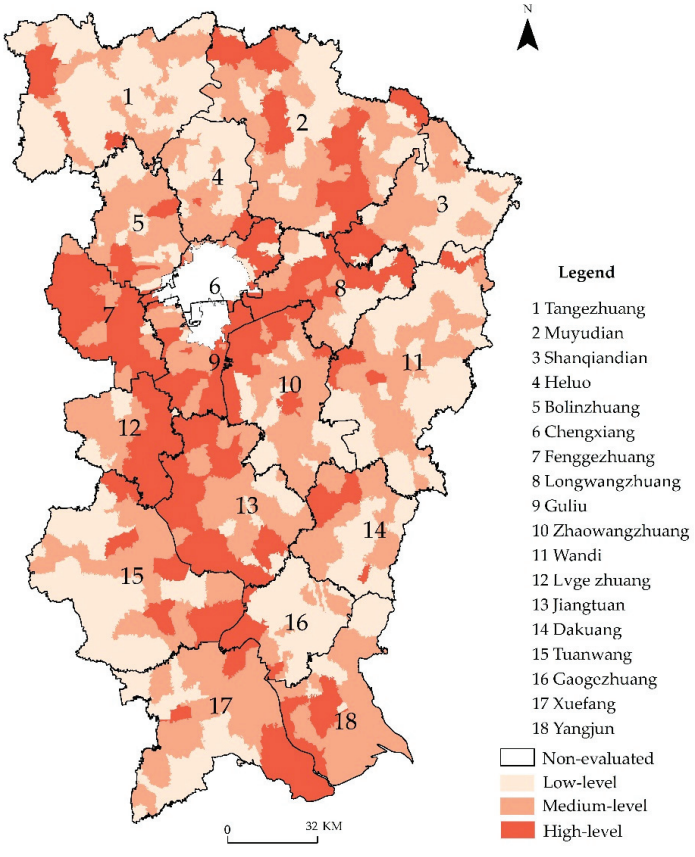


Figure 4. Evaluation results of villages' development in Laiyang County.

5.3. Identification of Villages' Development Types

5.3.1. Coupling Coordination between Natural Suitability and Socioeconomic Development Level

The average coupling degree C of the study area (Figure 5a) exceeded 0.86, indicating that the coupling degree of natural suitability and socioeconomic development level was high. According to statistics, there were 593 villages with high-level coupling, 119 villages with superior-level coupling, and 62 villages with low-level coupling. Although the amounts of suitable area in some villages in the west of Tuan Wang and Xue Fang were relatively high, the resource endowment and cluster-scale conditions were not very useful due to the large distances from the urban area, which also came with the cost of low social development levels.

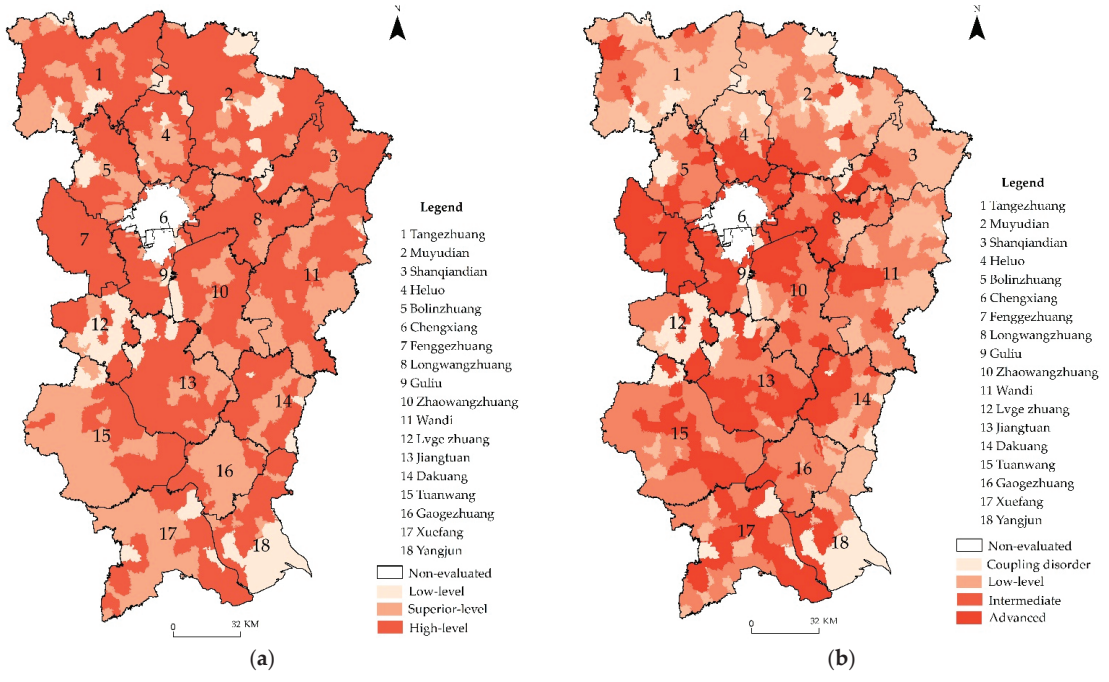


Figure 5. Coupling characteristics of village suitability and socioeconomic development: (**a**) Coupling degree; (**b**) Coupling coordination degree.

The coupling coordination degree D of natural suitability and socioeconomic development of the villages ranged from 0.38 to 0.71. According to division standard, there are four coupling coordination types, advanced coupling coordination of 247 villages, intermediate coupling coordination of 464 villages, low-level coupling coordination of one village, and disordered coupling of 62 villages. They had obvious spatial differences, which generally present a trend of taking the urban area as the center of the circle, gradually decreasing outwards, and high in the south and low in the north (Figure 5b). The advanced coupling coordination villages were scattered in the areas around each. Villages of the low-level coupling coordination and disordered coupling were mainly located in Muyudian, Heluo town, etc., and the suitability and socioeconomic development level of villages were low.

5.3.2. Villages' Development Types Identification

Integrating the four levels of natural suitability, three levels of socioeconomic development level, and four levels of coupling coordination, 17 coupling modes of natural suitability and socioeconomic development in the study area were obtained. Among them, the intermediate coupling coordination–medium suitability–medium level developmental villages were the most commonly found areas, containing 113 villages, constituting about 15% of the evaluated villages in Laiyang County. The socioeconomic development level in medium-level villages was higher than other villages, but these villages' coupling coordination degrees were higher; a change of natural suitability will drive a change of socioeconomic development level. High coupling coordination–high suitability–medium level development and intermediate coupling coordination–medium suitability–low level development villages accounted for 13% of the evaluated villages. The coupling coordination degrees in these villages were high.

Therefore, from the two aspects of rural natural suitability and socioeconomic development, combined with the degree of coupling coordination between them, the village development stages were divided into five types, using the combination matrix method

of multi-dimensional characteristics [55,56]. All types of coupling disorder (D1) and low coupling coordination (D2) villages were classified as the relocation and integration development. All villages of the intermediate coupling coordination (D3)-low-suitability were classified as the decreasing and improving development. The villages with medium and high combination in the type of advanced coupling coordination (D4) were classified as the urbanization development, and the rest of villages were classified as the construction and agglomeration linkage development based on the coupling coordination degree (Figure 6, Table 4).

The 237 urbanization development villages were located in the surrounding parts of urban areas, mainly guided by urbanization development, accounting for 31% of the evaluated villages. This type of village has obvious geographical advantages, abundant resources, a scale (population, area, etc.) advantage, regular shape, completed infrastructure, and gentle slopes. The radiation of towns and cities plays a vital role in the economic development of surrounding villages. Future development and revitalization of rural areas should rely on a better economic foundation and regional advantages, and develop green food, machinery manufacturing, health medical care, leisure tourism, logistics and other industries, so as to promote the integrated development of village industries and improve the level of ecological environment.

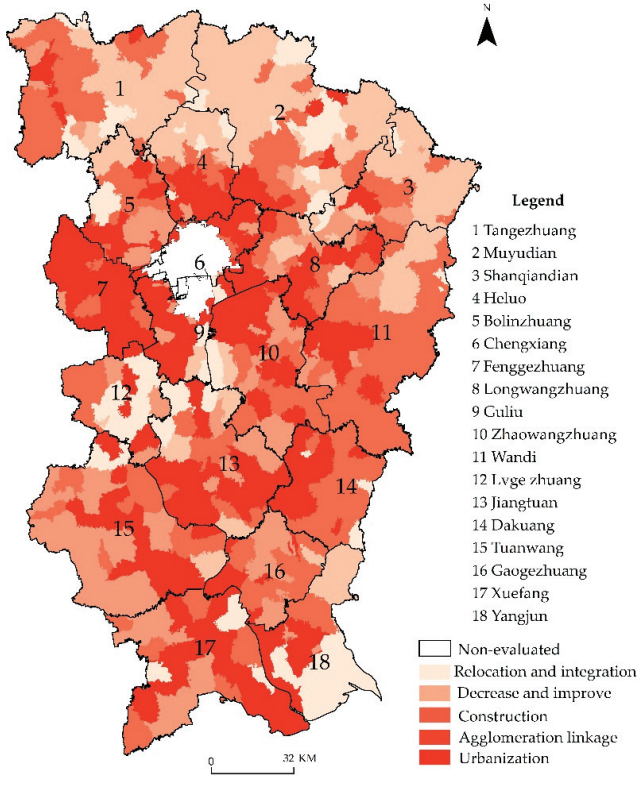


Figure 6. Identification of villages' development types in Laiyang County.

Table 4. Identification method of villages' development types in Laiyang County.

Coupling Degree of Compatibility	Natural Suitability [1]	Socioeconomic Development Level [2]	Number of Villages	Types	Combined
Coupling disorders (D1)	US	LD	25	Relocation and integration development	63
	US	MD	15		
	US	HD	22		
Low level coupling coordination (D2)	LS	LD	1		
Intermediate coupling coordination (D3)	LS	LD	59	Decrease and improve development	140
	LS	MD	63		
	LS	HD	18		
	MS	LD	98	Agglomeration linkage development	211
	MS	MD	113		
	MS	HD	3	Construction development	123
	HS	LD	67		
	HS	MD	43		
Advanced coupling coordination (D4)	LS	HD	10		
	MS	MD	33	Urbanization development	237
	MS	HD	71		
	HS	MD	99		
	HS	HD	34		

[1] Natural suitability, US = Unsuitable; LS = Low Suitability; MS = Medium Suitability; HS = Highly Suitable. [2] Socioeconomic development level, LD = Low-level development; MD = Medium-level development; HD = High-level development.

Construction development villages had a good economic foundation and relatively good basic facilities. The focus of development is to strengthen the construction of external transportation networks and improve the basic supporting facilities. There were 123 villages in this category, accounting for 16% of the evaluated villages. Villages of this kind are mainly distributed in Jiangtuan, Xuefang, Yangjun and other towns, with relatively abundant resources, large scale and regular shape, gentle terrain, complete basic infrastructure, and high-level development. In the future, the village development needs to optimize and perfect the external road transportation facilities, improve the external transportation convenience, and strengthen the connections with urban areas, towns and central villages. The construction of infrastructure and public service facilities should be improved to make life and production more convenient for villagers.

The natural conditions of the agglomeration linkage developing villages were moderately suitable, and the socioeconomic development was average. The key to these villages' development is to optimize the layout of the villages and develop specialty economies by relying on the advantages of unique resources. There were 211 villages in this type, accounting for 27% of the evaluated villages. This kind of village is relatively small, and it is mainly distributed in Heluo, Tuanwang, Wandi, and other jurisdictions. In this region, the village locations and traffic conditions are good, the infrastructure is relatively good, and the development level is medium; however, the relief of the terrain is large, and thus, development is limited by the natural conditions. The settlements are small and scattered, the layouts of villages are unreasonable, and the suitability is medium. In the future, such villages can merge scattered village lands through village planning so as to make villages contiguous and layout optimized. Relying on industry and trade, trade circulation, and other resources, industrial development will drive economic development and realize the combination of agriculture and industry. At the same time, some relocated villages will be attracted to move in and expand the agglomeration scale so as to drive the common development of other surrounding areas and increase the income of the collective and villagers.

The natural conditions and infrastructure of the declining and improving development villages are insufficient, and the level of economic development is different. The crux of these villages' development is to reduce the size of villages, improve village infrastructure, and develop village economies. There are 140 villages in total, accounting for 18% of the evaluated villages. Such villages are mainly distributed in the towns of Yangjun, Muyudian, and Wandi. The villages have poor natural conditions, are far from the central urban areas and towns, have low-level external traffic conditions, are small in scale, and have insufficient resource conditions and infrastructure. In order to adapt to the law of social development, this kind of village can gradually reduce the scale of village land according to the population migration and the withdrawal of homestead in the future, and use the land economically and intensively. The infrastructure and people's working and living conditions should be appropriately improved. At the same time, the government should guide rural residents to transfer their agricultural land to large agricultural households and agricultural enterprises, expand the scale of agricultural production, and develop appropriate economies of scale.

Relocation and integration development villages are not suitable for residential development, so they need to be relocated to develop primary, secondary, and tertiary industries and integrate with the new villages for development. There are 63 villages in this category, accounting for 8% of the total number of villages in Laiyang County. This kind of village is mainly distributed in towns such as Muyu Dian, Dakuang, Wandi, and Yangjun. These villages have many hidden geology disasters, low-level living conditions, distanced locations, small areas, harsh ecological environments, unsuitability for living, and continued construction of infrastructure and public service facilities. These villages should be gradually relocated and merged into nearby towns or central villages. Additionally, then, they can develop secondary and tertiary industries in order to integrate with local development. The original village land can be reclaimed for arable land, ecological land, etc., so as to develop ecological agriculture, sightseeing agriculture, high-tech agriculture, etc., and promote socioeconomic development. At the same time, the relocated villagers should be guided to transfer their farmlands to large agricultural households and agricultural enterprises, to expand the scale of agricultural production, and to develop appropriate economies of scale.

5.4. Discussions

The identification of villages' development types is an important part of the classification and promotion of rural revitalization, rural planning, and territorial spatial planning. Scientifically and reasonably identifying the types of village development and putting forward the corresponding development strategies have become the key to promoting village development and optimizing village layout. This study established a comprehensive framework containing natural and socioeconomic aspects to identify the villages' development types. The villages in Laiyang Couty were used to examine the framework. The study found that this framework can group the villages in more feasible and reliable ways.

A village is a complex of natural environment and socioeconomic system. Researchers have studied the identification of villages' development types by constructing the evaluation system of a village development classification index [57]. The natural environment is the background condition of rural development, and the evaluation of natural suitability is one of the preliminary basic works of rural development. Priority should be given to evaluate whether it is restriction for village development. If it is not restricted, the suitability and its degree will be evaluated. The natural suitability/restriction evaluation, undertaken by using the combined method of the modified multiplication-weighted summation model, made the evaluation results more objective and has feasibility for replication. Based on the "bucket" principle, the restriction of some factors played decisive roles in the villages' natural suitability, and it was shown that some factors over their limit values were not suitable for the development of the village [44]. In terms of research methods,

an additive model is widely used, but it requires the evaluation factors to be independent of each other; otherwise, it will cause the information repetition among the evaluation factors, and the suitability degree cannot be objective and fully expressed. From the two perspectives of suitability/restriction and development level, the weighted summation model is supplemented with the multiplication model to make the evaluation result more scientific.

Villages with high natural suitability are usually accompanied by high levels of socioeconomic development. In addition to field survey and statistical data, the nighttime light data were added to more quantitatively evaluate the socioeconomic development of the study area. The results showed that the Luojia1-01 nighttime light image is suitable for the analysis of rural economic development, which expands the data source of this research and fills the gap in the application of the data in rural socioeconomic indicators. Due to the single use of nighttime light remote sensing data for the analysis of rural economy, the overall accuracy may not be high [38]. On the basis of the traditional quantitative economic statistical evaluation indexes, combined with nighttime light images to reflect the development of rural economy, this study realized the application of multi-source data fusion in rural socioeconomic indexes evaluation and also realized the test of nighttime light images in rural areas.

Although the framework used in this study can classify the village according to their natural and socioeconomic conditions, there are some limitations that shall be noted. In the application of Luojia1-01 nighttime light images, only one phase of image was selected; multiple nighttime light images can be fused for in-depth analysis in the future. In addition, when we selecting indicators, we mainly considered the key indicators affecting the development of rural areas and other relevant factors, such as special policies; the views of the villagers are considered less. The views of local residents also have an important impact on the future development of the villages, but the subjectivity is relatively strong, and it is not easy to quantify. How to set up a quantitative estimation system to accurately reflect the wishes of the local residents is left to be explored in the future study.

6. Conclusions

This study constructed a comprehensive natural–socioeconomic framework to identify villages' development types based on multi-source data; introduced modified multiplication-weighted summation and the coupling coordination degree model, and divided the villages into five development types in the study area. The proposed framework can provide a basis for rural revitalization and development planning. The main conclusions are listed below:

(1) The spatial distribution trend of natural suitability is "high in the southwest and low in the northeast," and the socioeconomic development level overall presents a "high–medium–low" distribution circle trend with the urban area as the center.

(2) The coupling coordination degree between natural suitability/restriction and socioeconomic development level is relatively high. The coupling coordination degree has obvious spatial distribution differences, with the urban area being the center, and the coupling being high in the south and low in the north. It gradually decreases from the inside to the outside.

(3) Villages' development types include urbanization development, construction development, agglomeration and linkage development, decreased or improved development, and relocation and integration development. A development suggestion of each type was proposed according to their advantages and disadvantages.

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References

1. Geoff, W.; Hu, Z.P.; Sanzidur, R. Community Resilience in Rural China: The case of Hu Village, Sichuan Province. *J. Rural Stud.* **2018**, *60*, 1–38.
2. Jaehee, H.; Jonghoon, P.; Seongwoo, L. The Impact of the Comprehensive Rural Village Development Program on Rural Sustainability in Korea. *Sustainability* **2018**, *10*, 2436.
3. Zhou, T.; Jiang, G.H.; Ma, W.Q.; Li, G.Y.; Qu, Y.B.; Tian, Y.Y.; Zhao, Q.L.; Tian, Y.Y. Dying villages to prosperous villages: A perspective from revitalization of idle rural residential land (IRRL). *J. Rural Stud.* **2021**, *84*, 45–54.
4. Xie, Z.; Zhang, F.R.; Lun, F.; Gao, Y.; Ao, J.; Zhou, J. Research on a diagnostic system of rural vitalization based on development elements in China. *Land Use Policy* **2020**, *92*, 104421. [CrossRef]
5. Chatzichristos, G.; Nagopoulos, N.; Poulimas, M. Neo-Endogenous Rural Development: A Path Toward Reviving Rural Europe. *Rural Sociol.* **2021**, *3*, 1–27.
6. Chatzichristos, G.; Hennebry, B. Social Innovation in Rural Governance: A Comparative Case Study Across the Margin-alised rural EU. *J. Rural Stud.* **2021**, *6*, 4.
7. Gorbenkova, E.; Shcherbina, E.; Belal, A. Rural Areas: Critical Drivers for Sustainable Development. *IFAC-PapersOnLine* **2018**, *51*, 786–790. [CrossRef]
8. Tiutiunikov, A.; Pechenevsky, V.; Chernysheva, I.; Zakshevskii, G. Agrarian Structure Transformation and Rural Development in Russia: A Scientific Review. In *International Conference on Policies and Economics Measures for Agricultural Development (AgroDevEco 2020)*; Atlantis Press: Paris, France, 2020; pp. 361–365. [CrossRef]
9. Bruno, L.; Paulina, A.; Abigaïl, F.; Jean-François, L.; Eric, S.; Jeimar, T. Research on Climate Change Policies and Rural Development in Latin America: Scope and Gaps. *Sustainability* **2017**, *9*, 1831.
10. Tang, D.; Li, B.; Qiu, Y.; Zhao, L. Research on Urban and Rural Coordination Development and Its Driving Force Based on the Space-time Evolvement Taking Guangdong Province as an Example. *Land* **2020**, *9*, 253. [CrossRef]
11. Anna, I. Overview of Contemporary Issues of Sustainable Rural Development in Russian Terms of Existing Differences between Regions. *Econ. Agric.* **2014**, *61*, 331–345.
12. Hashemi, N.; Ghaffary, G. A Proposed Sustainable Rural Development Index (SRDI): Lessons from Hajij village, Iran. *Tour. Manag.* **2017**, *59*, 130–138. [CrossRef]
13. Yin, X.M.; Chen, J.; Li, J.Z. Rural Innovation System: Revitalize the Village for a Sustainable Development. *J. Rural Stud.* **2019**, *10*, 14.
14. Li, J.; Liu, Y.; Yang, Y.; Jiang, N. County-rural revitalization spatial differences and model optimization in Miyun District of Beijing-Tianjin-Hebei region. *J. Rural Stud.* **2019**, *10*, 12. [CrossRef]
15. Cheng, L. China's rural transformation under the Link Policy: A case study from Ezhou. *Land Use Policy* **2021**, *103*, 105319. [CrossRef]
16. Amir, A.F.; Ghapar, A.A.; Jamal, S.A.; Ahmad, K.N. Sustainable Tourism Development: A study on Community Resil-ience for Rural Tourism in Malaysia. *Procedia-Soc. Behav. Sci.* **2015**, *168*, 116–122. [CrossRef]
17. Ristić, D.; Vukoičić, D.; Milinčić, M. Tourism and sustainable development of rural settlements in protected areas-Example NP Kopaonik (Serbia). *Land Use Policy* **2019**, *89*, 104231. [CrossRef]
18. Claudio, L.; Vincenzo, G.; Luigi, M.; Agostino, G.; Alfonso, S. Exploring the features of agritourism and its contribution to rural development in Italy. *Land Use Policy* **2017**, *64*, 383–390.
19. Bielska, A.; Sta'nczuk-Gałwiaczek, M.; Sobolewska-Mikulska, K.; Mroczkowski, R. Implementation of the Smart Village concept Based on Selected Spatial Patterns–A Case Study of Mazowieckie Voivodeship in Poland. *Land Use Policy* **2021**, *104*, 105366. [CrossRef]
20. Van Gevelt, T.; Holzeis, C.C.; Fennell, S.; Heap, B.; Holmes, J.; Hurley Depret, M.; Jones, B.; Safdar, M.T. Achieving Universal Energy Access and Rural Development Through Smart Villages. *Energy Sustain. Dev.* **2018**, *43*, 139–142. [CrossRef]
21. Lu, T.; Yu, T. Reconstruction of Rural Social Space in Tourist Destinations Based on Social Network Analysis: A Case Study of Shi Wa Beautiful village, Nanjing City. *Sci. Geogr. Sin.* **2020**, *40*, 1522–1531.
22. Zhou, W.; Cao, Y.G.; Wang, J.; Yuan, C.; Qiao, L.Y. Suitable Appraisal and Judgement on Relocation and Annexation in Village Reconstruction Planning. *China Land Sci.* **2011**, *25*, 61–66.

23. Li, Y.; Bu, C.; Cao, Z. Village Classification System for Rural Vitalization Strategy: Method and Empirical Study. *J. Nat. Resour.* **2020**, *35*, 243–256.
24. Qiao, L. Village Type Identification and Rural Revitalization Strategy: A Case Study of Zhangzi County of Shanxi Province. *Prog. Geogr.* **2019**, *38*, 1340–1348. [CrossRef]
25. Xie, Z.; Zhang, F.; Chen, S. Development Types of Rural Revitalization Based on the Identification of Development Elements in China. *Resour. Sci.* **2019**, *41*, 1048–1058.
26. Yang, Y.Y.; Bao, W.K.; Liu, Y.S. Coupling coordination analysis of rural production-living-ecological space in the Bei-jing-Tianjin-Hebei region. *Ecol. Indic.* **2020**, *117*, 106512. [CrossRef]
27. Xu, K.; Fang, Y.G. Rural Multi-Function Evaluation and Evolution Characteristics in Liaoning Province. *Econ. Geogr.* **2021**, *1*, 17.
28. Liu, X.; Liu, Y.; Rui, Y.; Zhang, J.; Zhao, X. Evaluation of sustainable agriculture and rural development in agro-pastoral ecotone under climate change: A comparative study of three villages in the Shenfu coalfield, China. *J. Rural Stud.* **2020**, *12*, 16. [CrossRef]
29. Qu, Y.B.; Jiang, G.H.; Ma, W.Q.; Li, Z.T. How does the rural settlement transition contribute to shaping sustainable rural development? Evidence from Shandong, China. *J. Rural Stud.* **2021**, *82*, 279–293.
30. Guo, X.Y.; Hu, Y. Construction of Evaluation Indexes System of Rural Revitalization Level. *Agric. Econ. Manag.* **2020**, *5*, 5–15.
31. Souknilanh, K.; Magnus, A.; OLA, H. Monitoring Economic Development from Space: Using Nighttime Light and Land Cover Data to Measure Economic Growth. *World Dev.* **2015**, *66*, 322–334.
32. Zhong, L.; Liu, X.S. Application potential analysis of LJ1-01 new nighttime light data. *Bull. Surv. Mapp.* **2019**, *7*, 132–137.
33. Liu, H.; Luo, N.; Hu, C. Detection of County Economic Development Using LJ1-01 Nighttime Light Imagery: A Comparison with NPP-VIIRS Data. *Sensors* **2020**, *20*, 6633. [CrossRef]
34. Zhang, G.; Guo, X.; Li, D.; Jiang, B. Evaluating the Potential of LJ1-01 Nighttime Light Data for Modeling Socio-Economic Parameters. *Sensors* **2019**, *19*, 1465. [CrossRef] [PubMed]
35. Zou, Y.J.; Yan, Q.W.; Huang, J.; Li, F. Modeling the Population Density of Su-Xi-Chang Region Based on Luojia-1A Nighttime Light Image. *Resour. Environ. Yangtze Basin* **2020**, *29*, 1086–1094.
36. Wang, L.Y.; Fan, H.; Wang, Y.K. Improving population mapping using Luojia 1-01 nighttime light image and loca-tion-based social media data. *Sci. Total Environ.* **2020**, *730*, 139148. [CrossRef] [PubMed]
37. Li, X.Q.; Zheng, H.; Zhang, G.; Guo, X.Y.; Liu, W.L. Analysis of Luojia1-01 indexes based on night light imagery. *J. Geomat.* **2020**, *45*, 8–15.
38. Ma, G. Coupling Analysis of New Urbanization and Rural Revitalization in Henan. *Chinese J. Agric. Resour. Reg. Plan.* **2020**, *41*, 103–112.
39. Ma, W.; Chen, Y. Coupling Coordination Relationship and Spatial Difference between Population Urbanization and Land Urbanization. *Stat. Decis.* **2020**, *36*, 114–116.
40. Xu, W.-X.; Li, L.; Zhou, J.-P.; Liu, C.-J. The dynamic evolution and its driving mechanism of coordination of rural rejuvenation and new urbanization. *J. Nat. Resour.* **2020**, *35*, 2044–2062. [CrossRef]
41. Qu, Y.; Zhang, F.R.; Guo, L.N. Evaluation of Rural Residential Land Consolidation Classification and Priority of Pinggu District in Beijing. *Trans. CSAE* **2011**, *27*, 312–319.
42. Wang, Z.L.; Yang, Q.Y.; Li, J.; Wang, Y.; E, S.X.; Yang, H.; Sun, S.R. Optimization Strategy of Rural Settlement Layout in Mountainous Urban Fringe Area: A Case Study of Shichuan Town in Yubei District of Chongqing. *Econ. Geogr.* **2019**, *9*, 182–190.
43. Yu, Y.; Zhang, Y. Coordinated Development of New Urbanization and Rural Revitalization in Zhejiang Province—An Empirical Analysis Based on Coupling Theory. *Gov. Stud.* **2020**, *36*, 43–49.
44. Wu, C.F. *Investigation and Evaluation of Land Resources*; Agricultural Press: Beijing, China, 2008; pp. 126–128.
45. Han, X.; Cao, T. Study on ecological environment quality evaluation of the energy consumption pollution treatment in industrial parks. *Environ. Sci. Pollut. Res.* **2021**, *28*, 28038–28057. [CrossRef]
46. Milada, Š.; Antonín, V. The Relationship Between Public Transport and the Progressive Development of Rural Areas. *Land Use Policy* **2017**, *67*, 107–114.
47. Zheng, X.M. Research on Evaluation Index System of Rural Revitalization Potential based on Classification Promotion. *Soc. Sci.* **2019**, *6*, 36–47.
48. Shi, Q.J.; Han, X.Y.; Cao, G.Z. Classifying Villages for Planning and Construction Guidance: Index Development and Application in China. *Hum. Geogr.* **2017**, *6*, 121–128.
49. Han, X.Y.; Yan, F.Y. Research on the Comprehensive Evaluation and Types Recognition of Rural Development under Rural Revitalization. *China Popul. Resour. Environ.* **2019**, *29*, 156–165.
50. Herzberg, R.; Pham, T.G.; Kappas, M.; Wyss, D.; Tran, C.T.M. Multi-Criteria Decision Analysis for the Land Evaluation of Potential Agricultural Land Use Types in a Hilly Area of Central Vietnam. *Land* **2019**, *8*, 90. [CrossRef]
51. Cong, X. Expression and Mathematical Property of Coupling Model, and Its Misuse in Geographical Science. *Econ. Geogr.* **2019**, *39*, 18–25.
52. Wu, W.; Long, Y.; Yu, Q. Coupling Characteristics Between Cropland Intensification and Large-Scale Utilization in China. *Chin. J. Agric. Resour. Reg. Plan.* **2020**, *41*, 12–19.
53. Yang, X.; Zhang, D.; Liu, L. Measurement of Coupling Coordination Between New Urbanization and Ecological Envi-ronment in Ecologically Fragile Areas. *Stat. Decis.* **2020**, *36*, 128–132.

54. Wang, Z.; Zhao, S.; Yang, X. Study on the Evolvement of Coupling Coordination Between Transportation Network and Tourism Tesort of Urban Agglomeration—A Case Study of Chang-Zhu-Tan urban Agglomeration. *World Reg. Stud.* **2020**, *29*, 962–972.
55. Niu, H.P.; Yang, X.Y. Optimization of Rural Residential Area Distribution in Mengzhou City Based on Coupled Coordination Degree. *Trans. Chin. Soc. Agric. Mach.* **2019**, *50*, 153–162.
56. Zhang, R.J.; Jiang, G.H.; Wang, M.Z. Layout Classification of Rural Settlement Based on Combination of Mul-ti-dimensional Characteristics. *Trans. Chin. Soc. Agric. Mach.* **2015**, *31*, 286–292.
57. Bu, X.; Pu, L.; Shen, C.; Xie, X.; Xu, C. Study on the Spatial Restructuring of the Village System at the County Level Oriented toward the Rural Revitalization Strategy: A Case of Jintan District, Jiangsu Province. *Land* **2020**, *9*, 478. [CrossRef]

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Territorial Effects of Shared-Living Heritage Regeneration

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Abstract: The paper presents further steps of study started by authors in recent years, as part of the widest international research collaboration, which focuses on shared life and regeneration of abandonment of rural settlements as strategies for the development of sustainable territories. This research aims to understand how the regeneration of ancient community buildings impacts on the sustainable development of the local context. To understand these effects, the research considered four traditional typologies of community buildings, from different cultures: Tulou (China), Cascina (Italy), Hacienda (Mexico), and Marae (New Zealand). Among the tens/hundreds of contemporary regeneration interventions, three contemporary projects per each of these typologies have been selected. To assess the territorial impact of the projects a new approach has been defined using Expert Interviews as the methodology, so as to be able to have an assessment directly by experts in the fields of regenerative projects and sustainable development. The Expert Interviews were held based on a questionnaire that assessed the effects of the projects. For the evaluation of the projects, two categories of indicators have been selected: (1) United Nations SDGs, (2) architectural regeneration indicators generated by the study "The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool", by Francesca Nocca, published in Sustainability (2017, 9, 1882). The research outputs show how the urban-architectural regeneration of these historical typologies can be clearly associated with indications of sustainable development. The results also show that in all four cultures the regeneration of historic buildings provides many benefits to local communities by successfully mixing different income groups and the inclusion of marginalized or vulnerable groups.

Keywords: shared heritage; architectural design; heritage regeneration; community buildings; expert interview method; sustainable development goals (SDGs); cultural landscape; territorial impacts and sustainability; rural-urban

1. Introduction

The idea that regeneration practices are related to the sustainable development of territories, cities, and local communities is now established in contemporary academic literature as well as in common awareness [1,2]. In fact, the association between regenerative practices and sustainable development is not limited to the academic sphere but it is strongly accepted both by the urban-architectural design practice, and the government sector which increasingly promotes regeneration projects to encourage sustainable solutions [3–5]. Moreover, these two aspects together bring about results in

other fields, such as tourism [6,7], disaster prevention [8], urban planning [9,10], and decision-making processes [11].

The work presented in this article focuses on the role sustainable territorial development has in those regenerative interventions made using traditional types of collective buildings. The decision to focus on traditional collective buildings is dictated by the curiosity to observe how buildings, which traditionally have been fundamental elements in defining the urban-architectural structure and the social rules of almost all cultures [12], react to regenerative projects that often changes the building functional program and its relationship with the context.

Projects that intervene on historical heritage—and, in particular, on architectural typologies that often represented the symbol of a community or, furthermore, were the very essence of a society [12]—are now very common. It is therefore urgent to understand how territories and local communities are impacted by project regeneration, by being able to identify, first, the positive and negative effects and, second, define key design decisions on how to deal with these projects.

1.1. Shared Life in History

Active participation in community life has always been a key factor for human communities and the spatial organization of communities allows this type of involvement. For this, innumerable examples of community buildings can be found in almost all human housing cultures. Community buildings played a fundamental role in these cultures as promoters of the sense of belonging to a community and a protective element from external dangers. This historical heritage, which in the article will be defined as Shared Living Heritage (SLH), has still remained as a symbol of the various housing cultures, even if often the functions have changed or the buildings have fallen into disuse. Around them, community members can still recognize each other and retain a clear identity so that they can be considered within the so-called historical landscape elements (HLE) [13–17], or "fundamental components of cultural landscapes, becoming important bearers of collective services" [13].

1.2. Regeneration as Sustainable Practice in Contemporary Territories

Common regeneration projects in contemporary territories are seen in historic places whether urban or rural, particularly as an evolutionary necessity of community in response to many of the challenges posed by worldwide changes affecting the way of many people's lives [18,19]. The need to rediscover natural forms of relationships pushes to think of new forms of producing, living, and experiencing. Therefore, we see more abandoned buildings and other kinds of historic properties are becoming objects of regeneration as a way to establish new forms of communitarian living. Practices of social and environmental sustainability are combined, reducing consumption of land, landscape coherence, territorial intensification, and affordable way of life.

Since the early 1980s, the concept of counter-urbanization [20] became an answer to the issues of living in urban areas. In his seminal paper in 1985, Paul Cloke [20] argued that shortage in affordable housing, increase in basic service costs, the growth of rural economic activities as an alternative to unhealthy city life, teleworking/home office opportunities, and schedule flexibility in corporate activities, has triggered the possibility of living outside urban settings. Currently, there are several approaches to regeneration. From touristic to environmental services; from a more social/community-led approach to a more holistic perspective, the reality is that historic-rural settlements are used to comply with all the needs and desires of new generations eager to try something different from what they live nowadays [21,22].

1.2.1. Regeneration of Historical Heritage

In general, the regeneration of historical heritage interplays with many factors concerning the physical, environmental, economic, and social aspects. Among others, the communities recognize a historical site or building-specific values and identity.

Particularly in cultural and natural landscapes, a community advocates its value to sacred or historical/patriotic events, creating a sense of nostalgia. This reinforces the fundamental relationship between natural and built features, recognizing its profound legacy to the community. Therefore, it is important to consider the intrinsic value of the site when proposing a regeneration project and should account for these premises in order to be successful.

Regeneration strategies vary widely around the world, depending on the policies that each country has regarding preservation and stewardship, but also to the level of association and cultural recognition a site or building is exposed to. Each country has its own preservation measures promoting some sort of stewardship in order to take care of the regenerated site. Depending on the site, a private investor, a public-private agreement, a non-profit organization, and of course, the community itself, could be the principal steward of the historic regenerated site [23].

There are varied arguments as to whether we should regenerate heritage and for what purposes. On one hand, we found studies that celebrate the economic and social benefits that heritage conservation and regeneration brings to the community [24,25] but on the other, more skeptical authors argue that the reaction of nostalgic elements attached to the specific site, or the more personal motives that some community members may have to regenerate heritage, actually rejects a more organic, local, diverse, and authentic use of the space [26,27].

Several movements such as some branches of the new urbanism model, shared living practices, and cohousing strategies, have become an outstanding way to regenerate and reutilize historical heritage in urban and rural settings. These movements have found that old buildings and sites respond to dwelling necessities while celebrating key cultural elements of the community that would live within, disregarding bad habits of cultural appropriation and cliché redefinitions of authenticity.

Recognizing the living dimension of historic heritage sites to regenerate and reutilize them in a more sustainable approach, is a useful way to build a sense of community through social interaction and aspects associated with local heritage, as well as promoting community life and a sense of place.

1.2.2. Historic Urban Landscapes

The concept of Historic Urban Landscapes (HULs) is not new, but its potential in today's world is. The concept draws from experience in urban conservation and cultural landscapes, seeking to encompass values relating to intangible heritage, genius loci, authenticity, and integrity [28,29].

HULs extend beyond the traditional boundaries of historic cities or districts to encompass the larger territory of their urban, rural, and/or natural settings, which also require conservation and management. The physical character of HULs is defined as much by their urban and architectural traits as by their natural setting, the geographic elements that preceded them and shaped their growth, and the resulting viewsheds.

Managing an HUL focuses on the dual challenge of enhancing the vitality of historic cities and of integrating contemporary architecture in an emerging conceptualization of historic cities as historic urban landscapes [30]. Traditionally, the authenticity of a place has been linked to materials, design, workmanship, and setting—the importance of physical tangible evidence. However, the original character of some places was not defined by human-made elements but by natural formations or the more ethereal concept of genius loci. According to Gustavo Araoz [30], this apparent need to venerate and preserve the material legacy inherited from the past has been codified by conservation experts through the attribution of two types of values to the materiality of place: the aesthetic value and the historic value. This means that either the physical elements of these places contained communal memories or enriched the observer through sensory delight.

However, the HUL approach suggests that in historic cities the process of change per se can be an integral component of the significance of the place, and not only the aesthetic values. Association to historic or communal memories is as important as the new traces that are conceived through contemporary developments. The implications of allowing historic cities to continue to evolve along historic patterns have been explored, and experiments of individualistic "look at me" type of public

architecture, facadism, and buildings of unprecedented heights in close proximity to historic districts allow for the integration of the HUL discourse a key statement for an integrated approach linking contemporary architecture, sustainable urban development and landscape integrity based on historic patterns, building stocks and context [29].

There are two unrelated trends in the debate of regeneration of historic urban landscapes, one being a conceptual shift in the perception of the nature of heritage places, and the second related to the accelerating demographic pressure to increase urban density [28,30]. Historic cities are being treated as laboratories for experiments on high density, gentrification, and cultural appropriation, among others, directly affecting the cultural heritage and other tangible and intangible aspects of the site.

HULs planning interventions must be conceived as an integral part of the overall urban-management effort to bring socio-economic development and a better quality of life for the existing population. Shared-living in historic urban landscapes must be promoted not only to enhance stewardship and community management towards historic sites and buildings but also as part of a more sustainable approach, remembering Carl Elefante's [31] iconic phrase "The greenest building is the one that is already built".

Historic revitalization projects are relatively smaller than traditional new developments within the same areas since historic buildings share space composition attributes that do not necessarily qualify for the specific new functions. Intergenerational projects are more likely to succeed in HULs due to traditional neighborhood amenities, and a sense of remembrance for the elderly, as well as a sense of community for new generations.

Shared-living or cohousing communities can model good preservation of historic urban settings by successfully mixing residential incomes, stabilizing vulnerable or marginalized groups, redeveloping a small neighborhood block, and redesigning the way building retrofit is done. There are several examples of how historic places are converted into shared living projects. Examples are presented and discussed in this article.

There are many benefits in retrofit projects converted into shared communities, for instance, it prolongs senior resident independence; it sees more involvement and participation in volunteerism and local politics; and finally, it enables the ability of communities to collaborate with each other showing a potential effect within a larger community [32].

The notion behind the holistic management of historic landscapes is to secure their evolutionary development, considering issues of ecological sustainability as well as geo-cultural distinctiveness and identity. It is as much people-driven as it is artifact-driven. Management is focused on the inhabitants and others who conduct their daily lives within historic urban sites, without which it becomes difficult to serve a range of activities and the essential ingredient of a sense of place.

1.3. Literature Review, Knowledge Gap, and Research Question

Within this framework, it is clear how the current literature highlights (1) the great value that architectural typologies of shared living have for communities and territories and (2) the sustainable characteristics that often characterize the heritage regenerative projects. In addition to these macro-considerations, another aspect clearly emerges: (3) the introverted attitude of the original SLHs, which saw that closing themselves outwards had the possibility of protecting the community from external dangers. Actually, this last consideration can be extended also to other SLHs that the authors decided not to consider in this work to keep the research focus. Clear examples are the Kraal, the underground building of Matmata, or the Shabono [12,33–35]. Finally, (4) considering how these architectural enclosure providing the protection needed for have changed in the vast majority of cases, the research question that led to the development of this work emerges: now that these typologies are opening up to the local context—not dangerous anymore. Do SLH continue to be an element of valorization of local communities as well as a promoter for territorial sustainable development? And, in particular, what effects do these regenerative projects have on territories and local communities? Our research discusses how the urban-architectural regeneration of these historical typologies can often be clearly associated with indications of sustainable development.

2. Materials and Methods

To answer the research question, the Expert Interviews methodology has been adopted as the main strategy. The panorama of Architecture Research Methodology is extremely rich and interesting [36] and, in fact, this methodology is widely used by the scientific community in the architectural-urban context as a tool for analysis and interpretation of contemporary phenomena. As argued by Meuser and Nagel "The Expert Interview as a method of qualitative empirical research, designed to explore expert knowledge, has been developed considerably since the early 1990s" [37].

The Expert Interview methodology is widely discussed, and the existing literature review provides a very clear and structured theoretical framework. Basically, this methodology, particularly used in the interpretative social research, requires that authors ask opinions to people considered "experts in their field" with the aim of (1) exploring, (2) systematizing, or (3) theory-generating [38]. There are various reasons why such a methodology could be considered adequate in fields like the one of this research: first of all, the "fact that respondents are highly qualified in the analyzed question, eliminates the need to use additional screening and clarifying questions aimed at revealing true, but hidden from the interviewer respondent views" [39]. In essence, therefore, the data obtained have the reliability that does not require additional considerations and it is possible to obtain a good representation of the studied phenomenon with relative transparency and correctness. Furthermore, as a methodology, it is flexible enough, so that it can be applied individually (as in the case of this research) or in a context of triangulation of methods [37]. However, one should not lose sight of the fact that the Expert Interview is still an interview methodology that, although providing a privileged and more reliable point of view, always remains the representation of different points of view [37]. Undoubtedly, this reliability depends very much on the correct choice of experts and on the material provided for discussion.

Who to consider as an "expert" is, in fact, very important and assumes a central role in the organization of the process. Meuser and Nagel quoting the study of Hitzler, Honer, and Maeder, provide us the definition of an expert. An "expert" is a person, who has knowledge of his own area of interest and who, at the same time, possesses an "institutionalized authority to construct reality" [37]. The importance of defining experts is emphasized also by Libakova and Sertakova who highlight how the concept of "expert" must ensure certain criteria, including, "education and skills, position, related to the research topic, work experience in the subject in question, the degree of quality of the prior expert judgments, the level of public recognition, objectivity of the submitted ratings" [39].

At the same time, the quality of the material provided to the experts, so they can develop a clear idea of the topic of discussion and evaluation, is equally important. In this sense, preparing guidelines that highlight a shared common context is recognized as an extremely effective practice, guaranteeing comparability of the results and a focus on the relevant topics against a horizon of other possibilities [37].

According to the essence of an Expert Interview methodology, the research work was structured according to the following steps: (1) definition of the types of Shared Living Heritage (SLH) to be studied, contemplating the enormous differences between housing cultures all around the world; (2) definition of recent regeneration projects and collection of a sufficient quantity of material for in-depth case studies; (3) definition of the indicators useful for studying and analyzing the territorial effects of the projects and the territorial and community role assumed by the SLH following regeneration; (4) carrying out Expert Interview according to the methods recommended by contemporary academic literature, which will be better explained later; (5) collection and analysis of the results of the Expert Interviews.

2.1. Definition of the Four Shared Living Heritage (SLH) Typologies

According to the research objective, four architectural typologies have been defined with the following characteristics: (1) historical relevance as community building; (2) having been the object of several regeneration projects in the last decades; (3) possibility of access to a significant quantity of material, suitable for analyzing projects. Furthermore, the four typologies have been selected in four different geographical areas and consequently are expressions from different cultures.

The four selected typologies, which are explained in the following pictures, are Tulou (Fujian, China) [40,41], Cascina (Northern Italy, Europe) [40,42], Hacienda (Mexico) [40,43] and Marae (New Zealand) [40,44,45]. These typologies are explained in Figures 1–4, which represent some pages of the booklet prepared by the authors for the Expert interview. This choice was made because the authors want to show, as much as possible, the material used during the research. The 60-pages booklet used in the Expert Interview is available to everyone, at the following link (https://www.dropbox.com/s/tp6tuhetr9u8r8z/Expert%20Interview_booklet.pdf?dl=0) [46].

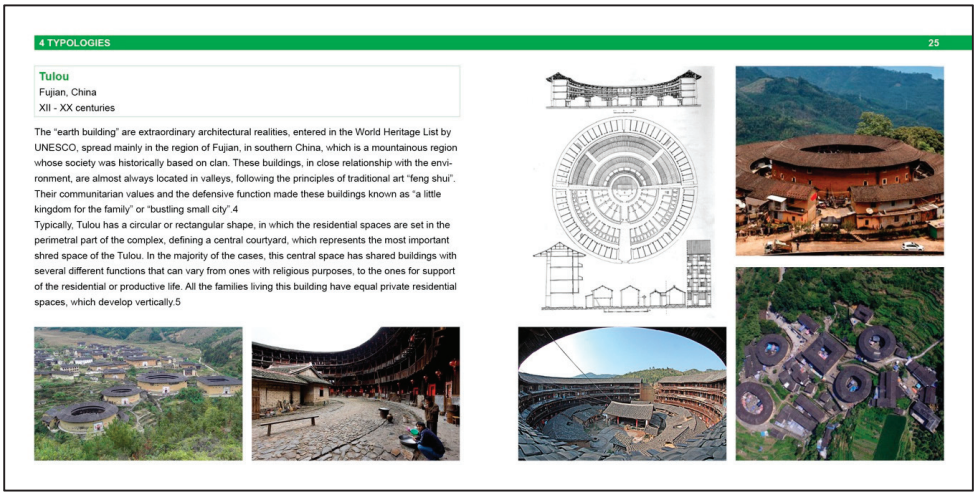


Figure 1. Pages of the booklet used during the Expert Interview to present the typology of "Tulou" to the experts.

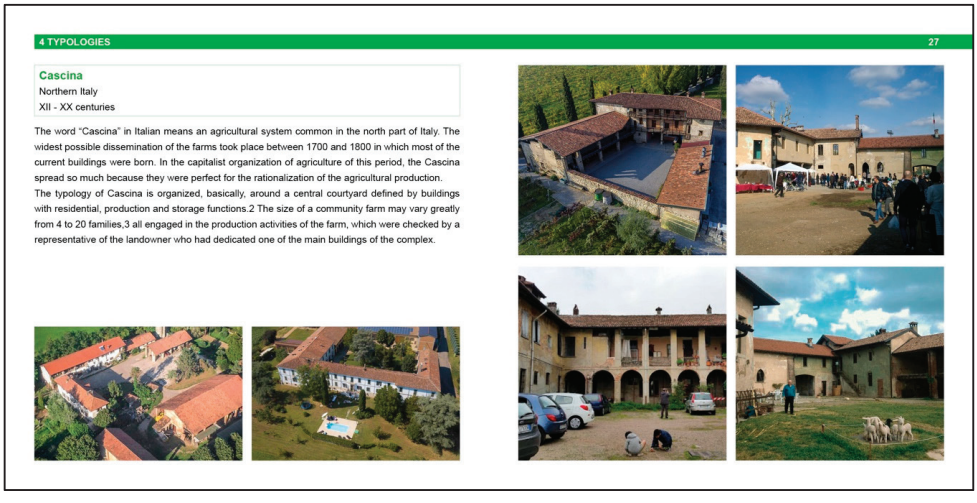


Figure 2. Pages of the booklet used during the Expert Interview to present the typology of "Cascina" to the experts.

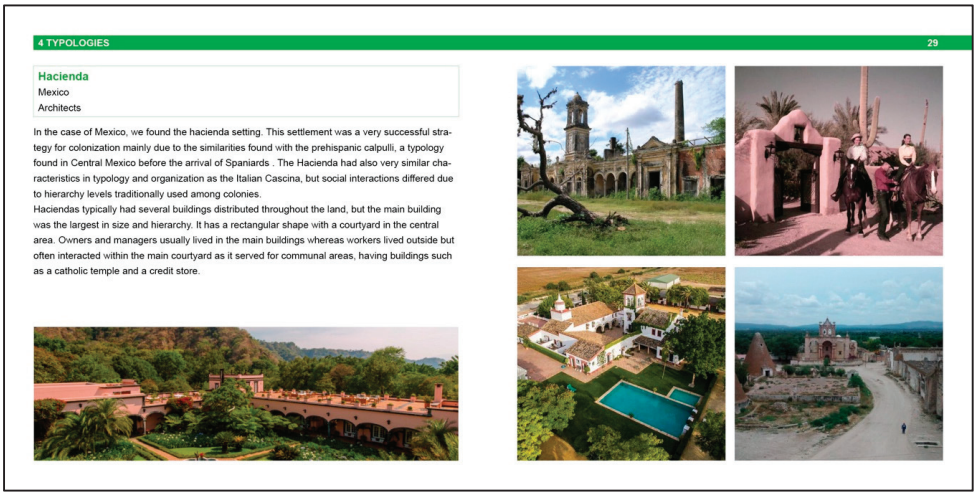


Figure 3. Pages of the booklet used during the Expert Interview to present the typology of "Hacienda" to the experts.

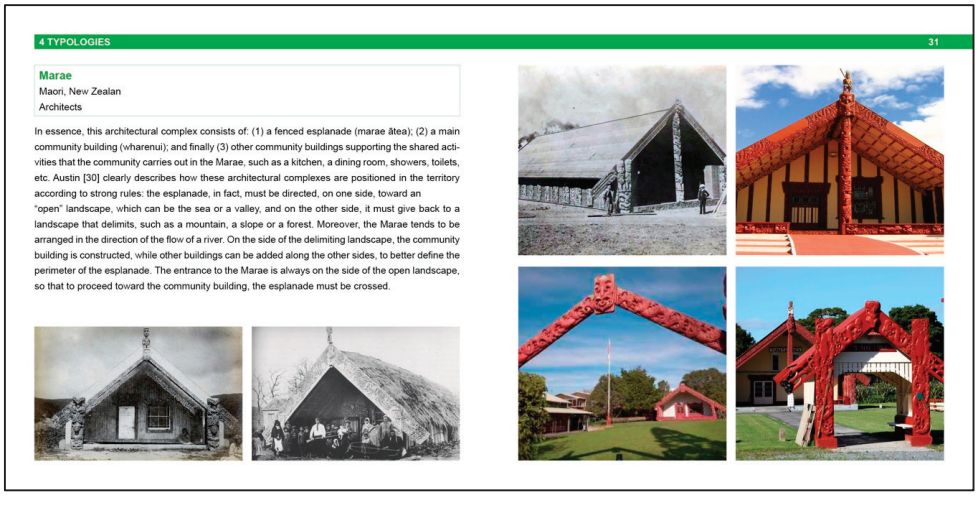


Figure 4. Pages of the booklet used during the Expert Interview to present the typology of "Marae" to the experts.

2.2. *Definition of the Regeneration Projects*

Three recently regenerated projects were selected for each typology. This decision was made considering a good balance between the need to provide a varied representation of the design approach (one or two cases per typology would not have been sufficient) and the need to have an in-depth analysis in terms of information useful for evaluating the project by the experts (a greater number of projects would have meant reducing the attention that the experts could provide analyzing the phenomena and, therefore it would have represented an incapacity to deeply analyze the projects).

Moreover, these projects have been selected from the panorama of local regeneration projects, excluding all those demolition and reconstruction of SLH that are oriented to the mere real estate market of selling houses in old-style buildings. Unfortunately, this is a contemporary tendency driven by real estate speculation, and not by the actual community and historical heritage regeneration.

To better represent and analyze the reality, the authors preferred not to account for "striking" cases published in architecture magazines or projects considered as "best practices". On the contrary, project selection considered these aspects: (1) consistency with the local tendency, which means that the projects reflect the features of other regeneration projects of the same typology; (2) reduced antiquity of the project; (3) abundant availability of material that describes the whole characteristics of the project. The first point, although introduces some bias specific to the authors, allows at the same time to reduce the number of projects necessary for the evaluation (as explained above) and to ensure that the results of the Expert Interview are as consistent as possible with reality. So, it should be noted how this selection, because of its methodological relevance, was the result of a long and deep process of reflection and study by the authors.

A narrative description of the projects is presented in Appendix A.

2.3. Choice of Existing Indicators to Study the Territorial Impact of Regeneration Projects

In order to guide the analysis of the projects and to be able to evaluate them, the authors decided to provide the experts with indicators that would highlight the two main aspects on which the research focuses: (1) the sustainability of the regeneration projects of the historical heritage and (2) the sustainability of the territorial impacts that characterizes these projects. Since the research does not aim to define new indicators, if not to evaluate the impact of these regenerative processes, the authors selected from the current academic literature two sets of indicators capable to guide the analysis and the study of these projects. So, to guide the experts in the evaluation, the following two sets of indicators have been considered:

- sustainability of the regeneration projects of the historical heritage: Cultural Heritage Indicators (CHIs). For the indicators concerning the practice of urban-architectural regeneration, the indicators developed by F. Nocca in the article " The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool" [47] have been taken into consideration. These indicators, in fact, highlight the aspects that the research wants to analyze related to the historical heritage. The indicators, as presented by Nocca have been lightly modified accordingly: the impact category of "Cultural value of properties/landscape" mainly referring to the "number of well-preserved/in ruin buildings" and to the "State of conservation of heritage/landscape asset" were removed. Although the degree of preservation is central to our research, it is not significant as a variable to consider for the evaluation of experts because it was standardized through the project selection process made by the authors so that all projects could be evaluated starting from the same level of "State of conservation of heritage/landscape asset". To see the list of indicators that compose this category, please refer directly to the text of Nocca [47].
- sustainability of the territorial impacts: Sustainable Development Goals (SDGs). In order to assess the sustainability of the territorial impacts of each project, it was decided to take into consideration the SDGs that are valid internationally as a reference framework for the territorial development practices that want to reach defined sustainability objectives [48]. Based on some previous research developed by the authors [49] and for the relevance that only some goals have in territorial and social implications, it was decided to consider just some SDGs. According to the relevance of some specific SDGs for territorial and social implications, as defined by the previous studies [49,50], the SDGs presented in Figure 5 have been considered. Hence, with the research question in mind, the targets and sub-targets of the SDGs relevant to shared life and regeneration of abandonment of rural settlements as strategies for the development of sustainable territories are taken into account and described thematically in order to provide precise information to the experts for their evaluation. Thus, according to the methodology for SDGs selection designed by Henzler et al. [50], the SDGs' selection process was structured as follows: (1) SDGs analysis; (2) Selection of SDGs relevant to shared life and regeneration of abandonment of rural settlements as strategies for development of sustainable territories; (3) Thematic description of the selected SDGs categories and indicators for impact category groups.

Sustainable Index (Sustainable Development Goals)

1- (SDG4) Quality Education

- By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes. - By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education. - By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university. - By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship. - By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations. - By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy. - By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development. - Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all. - By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries. - By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States.

2- (SDG8) Decent Work and Economic Growth

- Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries - Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors - Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services - Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead - By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value - By 2020, substantially reduce the proportion of youth not in employment, education or training - Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms - Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment - By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products - Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all - Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries - By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization

3- (SDG9) Industry, Innovation and Infrastructure

- Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all - Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries - Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets - By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities - Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending - Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States - Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities - Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities

Figure 5. *Cont.*

Sustainable Index (Sustainable Development Goals)

4- (SDG10) Reduced Inequalities

- By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average - By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status - Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard - Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality - Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations - Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions - Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies - Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements - Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries, African countries, small island developing States and landlocked developing countries, in accordance with their national plans and programmes - By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent

5- (SDG11) Sustainable Cities and Communities

- By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums - By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons - By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries - Strengthen efforts to protect and safeguard the world's cultural and natural heritage - By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations - By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management - By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities - Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning - By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels - Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

6- (SDG12) Responsible Consumption and Production

- Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries - By 2030, achieve the sustainable management and efficient use of natural resources - By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses - By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment - By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse - Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle - Promote public procurement practices that are sustainable, in accordance with national policies and priorities - By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature - Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production - Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products - Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities

7- (SDG13) Climate Action

- Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries - Integrate climate change measures into national policies, strategies and planning - Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning - Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible - Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

Figure 5. Graphical resume of the seven Sustainable Development Goals (SDGs) taken into account for the Expert Interview.

Both the sets of indicators are presented in the following Figures 5 and 6.

Heritage Index (Nocca F.)

1- Tourism and Recreation

(1) Touristic demand (2) Touristic supply (3) Economic vitality (4) Economic impact on local wealth

Tourism, defined as "a social, cultural and economic phenomenon related to the movement of people to places outside their usual place of residence, pleasure being the usual motivation", but also for other reasons "such as leisure, business, religious or health reasons and other purposes such as visiting friends and relatives", according to the International Recommendations for Tourism Statistics 2008, has become a pillar of economies, "a passport to prosperity". It is a sector that is able to transform cultural values into economic ones.

2- Creative, cultural and innovative activities

(1) Cultural demand; (2) Cultural supply; (3) Economic vitality; (4) Economic impact on local wealth; (5) Employment in cultural activities

There is a double relationship between the tourism sector and climate change: the tourism sector is contemporaneously both "a vector and a victim" of climate change (UNWTO Secretary-General, Taleb Rifai). The tourism sector cannot be excluded from the challenge to the global climate change; so, its impacts on climate change (that to date are underestimated) have to be considered, without forgetting the close relationship between tourism and global warming.

3- Typical local productions

(1) Creative firms; (2) Local production; (3) Employment in local production

Local production (craft and traditional products), as part of cultural heritage, is able to enhance local identity, too. Local specialties, representing local identity, are able to impart values of the community: identity values of the territory are expressed also through typical local products, when considering the strong link between the product and its place of origin. Companies, in particular smaller size ones, see in the typical products a chance to find a new competitive space against increasingly competitive markets by price.

4- Environment and natural capital

(1) Environmental preservation; (2) Green areas and facilities supply

Although the negative impacts (related to the double relationship between cultural heritage/cultural tourism and climate change) highlighted in the previous paragraph, the integrated conservation is able to produce also environmental benefits. The indicators related to this category rarely emerge from the analysis of the case studies: only three indicators (out of 177 referred to the 9 categories) in three case studies out of forty.

5- Social capital/cohesion and inclusion

(1) Social cohesion; (2) Sharing/collaborative economy initiatives; (3) Employment; (4) Social inclusion

Climate change can have negative impacts on integrity and authenticity of cultural heritage, damaging, and depriving the community of its "symbols". This is both physical and intangible deprivation. This draws also the attention to issues related to the enhancement of the local community, in addition to tourism and real estate issues. In this perspective, indicators related to the state of conservation of cultural heritage and the enhancement of local community (social cohesion and civic conscience) have to be considered.

6- Real estate and Financial return

(1) Real estate value; (2) Real estate supply; (3) Real estate development; (4) Public financial return

Real estate is positively influenced by investments in cultural heritage: the project areas and the surrounding areas usually revealed an increase in real estate value. Sometimes this increase can have negative impacts, such as gentrification phenomenon (interpreted as expulsion of the most vulnerable part of the population both in economic terms and cultural ones): local community and young people can no longer afford to buy/rent apartments because of rising prices; therefore, as has emerged from some case studies, many apartments remain unused for many years and the owners do not care about maintenance, causing the deterioration of them. Furthermore, the increase in property value produces a "touch and go" tourism because of the high prices to stay in the area object of intervention.

7- Cultural value of properties / landscape

(1) State of conservation of heritage/landscape asset

Cultural heritage expresses and maintains values and traditions of a city and its community, but its significance can be different among communities and also among members of the same community. It links past, present, and future but, at the same time, it has the potential for conflicts. Diverse social groups could have different values and beliefs, with different perceptions about what is relevant for their identity, attributing different values to a heritage place. The coexistence of these differences can represent a problematic issue and sometimes can be the cause of actions that could have negative impacts on heritage values.

8- Wellbeing

(1) Security; (2) Quality of services; (3) Housing quality; (4) Health

Mere economic indicators, as those referred to in the above-mentioned financial category, leave out many aspects that are not economically evaluable. They are able to evaluate the economic growth, but they do not represent people wellbeing. They alone are not significant because they are not able to capture information about wellbeing, happiness and the level of the life quality of citizens: it needs to go beyond the mere economic numbers. Economics should be only instrumental to the achievement of wellbeing.

Figure 6. Graphical resume of the eight Cultural Heritage Indicators (CHI) taken into account for the Expert Interview, as presented in the booklet.

2.4. Expert Interview to Evaluate the Projects

Once typologies were defined, projects were selected and the appropriate sets of indicators identified, the actual organization of the Expert Interview was carried out. In agreement with what emerged in the study of academic literature on the subject (already introduced at the beginning of

this section) and with the aim of reaching a phase of fruitful discussion with the experts, the authors worked in defining two aspects: choosing the correct experts and creating the material to be provided to the experts to guide the activity.

2.4.1. Experts and Material Definition

Guided by the seminal book of Bogner, Litting, and Menz [38], it was possible to determine the required number, and as well as to make the right choice of experts.

They were selected from professionals, academics, and non-academics, whose work in the fields of territorial sustainability and regeneration of the built heritage was well recognized. According to comparisons with other research and considering the differences among the "four contexts", the number of experts needed for this activity was set at 11. The names and short background of the experts are included in Appendix B.

Moreover, the authors took care that the experts (1) came from the four studied geographic areas and (2) that they had a cultural knowledge of at least two cultures of each typology and as well as a basic knowledge of the four cultures under investigation, (3) they have not only academic knowledge but are active in community affairs of the context under investigation regardless of their position [38]. The reason was that their mixed expertise (as both an academic and active person in the context) can be considered socially institutionalized—as defined earlier—and linked to a specific context, even though in a different way from the expertise fully grounded on the academic role. This was the case for instance of Expert number 04, 06, 08, 09, and 11.

The initial phase of screening for the selection of a pool of potential experts had been done on the basis of the authors' academic network. By keeping in mind the three basic characteristics of the experts as earlier mentioned, we immediately realized potential limitations for the application of this methodology. In fact, we had found two possible groups of experts for which this difference might have affected the assessments; namely, in some cases, the careers of some scholars were not yet long enough to be considered extraordinary in terms of research abilities, though there was already evidence of some results achieved. This was the example of Expert number 07 and 10. Of course, the opposite case has also occurred, for example of high-level scholars who had made outstanding careers in the past but had concluded their activities because of retirement. This was the case of Expert number 03, 05, and 06. Nevertheless, for our objectives, some kinds of abilities are more important than the current research performance that can offer a distorted picture of the relevant knowledge of one expert.

Hence, given these numerous problems that could have led to an improper selection of experts, we used two main elements before to complete the expert selection as suggested again by Bogner, Litting, and Menz [38]:

- Collecting standard discipline-scientific information about the scholars such as publications, citations, awards, memberships, and institutional and non-institutional engagement. These were all downloadable from Internet pages, the Web of Science, and other databases.
- Supplementing the previous standard information with "other" kinds of information from the experts, such as for example, other research interests, public engagement, activism in association (i.e., ONG), members of citizens' groups, as well as volunteers in welfare, social work, and similar fields.

In the final phase, crosschecking all these data and screening, a pool of potential experts had been listed. Thus, each expert was contacted directly to confirm the willingness to participate. From this last operation, the final pool of experts has been designated in Appendix B.

In brief, the eleven experts represent a mixed group of insiders and outsiders with regards to the four contexts studied. Moreover, they are divided into high ranked scholars in their field of studies and young researchers with evidence of some results already achieved such as Expert number 07, 10, and 11. On the other hand, the expert group is composed of young scholars that are also active in community affairs of the context and senior scholars with a background of social volunteering and/or

managerial direction of associations or public offices, such as for example the Experts number 04 and 08 and the Expert number 03, 05, and 06, respectively.

At the end of this delicate process, we can affirm that the final pool of the eleven selected experts was well balanced with regard to the above characteristics and quality as required for the experts' attributes in the scientific literature.

Meanwhile, as for the creation of the materials to be provided to the experts, a 60-page booklet was created collecting all the material necessary to carry out the activity. This booklet, which is not presented here for obvious reasons of spatial limitations, is available to everyone, at the following link (https://www.dropbox.com/s/tp6tuhetr9u8r8z/Expert%20Interview_booklet.pdf?dl=0) [46].

In the development of this article, however, various references are made to the contents of the booklet and some pages are presented as a template to show it as much as possible. This booklet is divided into four parts which present respectively: (1) objectives and methodology of the activity; (2) indicators to be used; (3) historical typologies; (4) projects to be analyzed.

- objectives and methodology of the activity: This section includes an introduction to the research rationale, the purpose of the expert's involvement, and the ways in which the research will be followed;
- indicators to be used: This section introduces both schematic and discursive presentation of the indicators selected to guide the evaluation of the experts. In addition to the indicators punctually explained, bibliographic references are provided for voluntary insights.
- historical typologies: In this section, each typology is presented through a textual description made by the authors. The goal is to make the experts confident with the typologies, also through various pictures and bibliographical references.
- projects to be analyzed: In this section, each project is presented through a text prepared by the authors (annex A), some links (i.e., to the architects' web page) for detailed study, and some pictures.

Besides the booklet, experts received instructions on the next steps to be implemented. It is pleonastic to highlight that all the experts have already proved knowledge on this matter.

2.4.2. Expert Interview Operating Method

Once the Experts' list was defined and the material sent to them, the authors decided to operate according to the following phases:

1. Site survey and first round of meetings: Site survey for the introduction to research and presentation of cases had been organized in September 2019 and January 2019 in China, Shanghai, and Milan, Italy, respectively. Authors and their research teams traveled and surveyed together numerous projects in China and in Lombardy, Italy, while another two field trips in Mexico and New Zealand were planned. Unfortunately, these last two field trips were not possible due to the COVID-19 pandemic outbreak, thus the local research teams completed this phase of the investigation. Regarding the experts' involvement despite the new circumstances generated by the pandemic and the differences in the geographical time-zone areas of the experts, telematic meetings were held using the Zoom platform. During these first meetings, the authors introduced the research to the experts, describing its objectives and methods, and presented the projects to avoid misunderstanding and to answer eventual questions. From these first meetings, some questions and considerations emerged, so to help the authors redefine the final questions, to which the experts would be asked to answer later. Some main considerations the experts shared were regarding the importance of the local context and the role of the local governments as well as the relevant differences among the four realities.
2. Refinement of the questionnaire to be submitted to the experts: based on the observations that emerged, the authors refined the questions to be submitted to the interview of experts.

3. Second round of meetings and Expert Interview: once the questions were completed on the basis of the experts' first observations, the final questionnaires were sent. For two weeks, the experts expressed their opinions supported by the questionnaire or during one-on-one meetings with the authors, who collected the answers within the same questionnaire. Due to differences in countries, the questionnaire was supported by a Google Form and by an Excel file. The answers were finally collected in a unique file that allowed the analysis and the development of the final results.

To summarize the whole process a figure of the flow of the activities carried out by the authors is illustrated in a simplified manner in Figure 7.

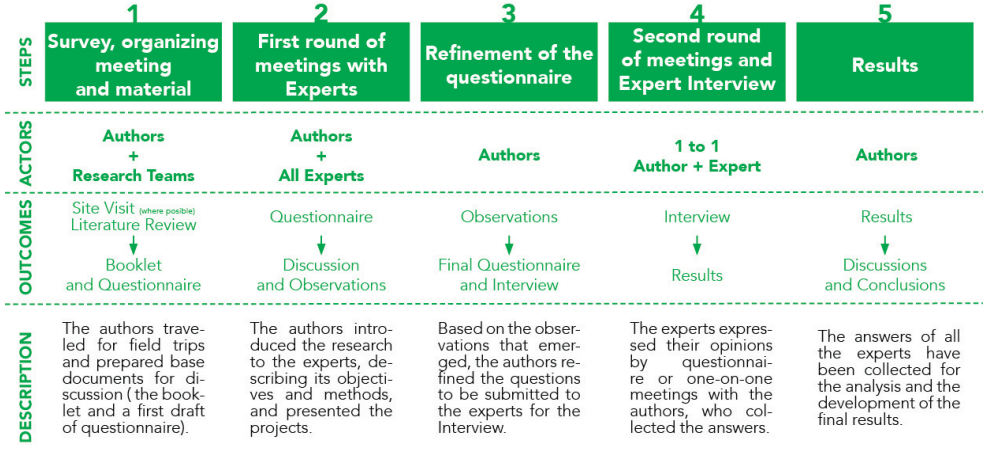


Figure 7. Workflow of the activities carried out by the authors and their research teams.

3. Results

The results presented here are grouped in tables, as average values of the experts' answers. All the answers from the experts are available in Appendix C.

Tables 1 and 2 represent the average obtained by each typology, with reference to the chosen indicators sets: selected SDGs (Table 1) and CHIs (Table 2). The authors asked the experts to evaluate according to a scale from 0 to 5, where 0 means that the characteristic specified by the indicator is totally absent and where 5 means that the indicator fully represents the characteristics of the project.

The results will be discussed in detail later, with the support of graphical representation. However, from these tables, it is already possible to clearly highlight the attitude, common to all the four typologies, to be considered as a sustainable practice, even if the Hacienda's regenerative projects showed some delays compared to Tulou and Cascina.

Table 1. Results of the Expert Interview, associating the regeneration projects of SLH with the SDGs.

	Tulou	Cascina	Hacienda	Marae
SDG 4. Quality Education	4.2	3.1	2.3	3.1
SDG 8. Decent Work and Economic Growth	3.2	3.5	3.2	2.9
SDG 9. Industry, Innovation, and Infrastructure	2.7	2.9	2.5	2.6
SDG 10. Reducing Inequality	4.1	3.2	2.2	3.4
SDG 11. Sustainable Cities and Communities	4.2	3.9	2.8	3.4
SDG 12. Responsible Consumption and Production	3.3	3.5	2.7	3.2
SDG 13. Climate Action	2.5	2.9	2.8	2.8
AVERAGE	**3.4**	**3.3**	**2.6**	**3.0**

Table 2. Results of the Expert Interview, associating the regeneration projects of SLH with the CHIs.

	Tulou	Cascina	Hacienda	Marae
1. Tourism and Recreation	3.0	3.5	4.6	3.2
2. Creative, cultural and innovative activities	4.1	3.8	3.3	3.8
3. Typical local productions	3.2	3.8	3.0	3.2
4. Environment and natural capital	3.2	3.7	3.7	3.4
5. Social capital/cohesion and inclusion	4.6	4.2	2.5	4.0
6. Real estate	2.3	4.1	4.0	3.4
7. Financial return	4.1	3.5	3.7	3.5
8. Wellbeing	3.9	4.0	3.8	3.5
AVERAGE	3.5	3.8	3.6	3.5

With reference to the first data, it can be seen that the average valuation referring to the CHIs is much more uniform than those referring to the SDGs, even if some indicators move from this tendency: very low values emerge for the Chinese Real Estate. At the same time, very low values emerge for the Social Capital/cohesion and inclusion for the Mexican Hacienda.

By combining the four typologies in this table (Table 3), it appeared that the CHIs indicators had higher values and rarely deviate from the average. On the contrary, SDGs have differences in values and average values. Namely SDG 9 and SDG13 achieved the lowest values, SDG 11 the highest, and the SDG4, SDG8, SDG10, SDG12 did not deviate as much from the average nor from the disaggregated values. This preliminary observation of these simplified values was significant because it indicated which CHIs indicators and which SDGs the four regeneration projects contributed to more. Regarding the Cultural Heritage Indicators (CHI), it was interesting and also comforting to see the regeneration projects were more effective in terms of creative, cultural, and innovative activities (indicator 2), social capital/cohesion (indicator 5), and wellbeing (indicator 8). This was the same for the SDGs values, as they reveal that the SDG11 Sustainable Cities and Communities was the goal on which the regeneration projects contributed more to the four typologies. On the contrary, it was necessary to underline that the SDG9 Industry, Innovation and Infrastructure, and SDG13 Climate Action, were the two goals with the lowest values. This was due to the fact that in rural areas industry, innovation, and infrastructure along with climate actions were not yet fully considered central in the whole process of regeneration. It could be determined also by the fact that infrastructures, innovation as well as climate change actions are seen as in charge to the central government due to many reasons such as, for instance, the huge investments needed for infrastructural projects. This insight is already a preliminary validation of the need to define normative and superordinate design actions for sustainable development of territories (key design decisions) as it is discussed in the next section.

Table 3. Results of the Expert Interview, resuming the results for the CHIs and the SDGs indicators. In grey color are the results of the indicators that had reach the higher values.

	CHI								SDGs						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**4**	**8**	**9**	**10**	**11**	**12**	**13**
Average indexes	3.6	3.8	3.3	3.5	3.8	3.5	3.7	3.8	3.1	3.2	2.7	3.2	3.6	3.2	2.8
Average categories	3.6								3.1						
Total average	3.4														

3.1. Graphical Representation of the Results

In order to highlight the aspects considered, the results of the Expert Interviews were represented in diagrams. Representations based on two types of diagrams have been chosen:

- Cartesian diagram—individual projects located in a Cartesian plan defined by the dimensions of sustainability (SDGs) and regenerative approach (CHIs). Each project finds its place in the plan

thanks to the coordinates given by the average values obtained in the Expert Interview for the categories of SDGs and CHIs. Additionally, the projects of each typology have been represented with the same color, so to allow to underline the behavior of the four typologies. Moreover, lines connect the points of the three projects, so to create an area, which will allow the authors to find additional characteristics and behaviors for each typology. This chart allows an overview of the performances of each project and typology related to their impacts on territories, in terms of sustainable development and regenerative approach.

- Radar—the behavior of the four regenerated SLH typologies are represented on the basis of the values they reached for the two sets of indicators. Two diagrams have been created: one for the CHIs indicators and one for the SDGs. Unlike the previous diagram, both of these charts allow for highlighting the most important typology behaviors with respect to the single indicators, thus arriving at more detailed and deep observations.

3.1.1. Relation among Projects, Typologies, SDGs and CHI

This Cartesian Diagram shows the results of the four different typologies, highlighting how each one has its own characteristics in terms of territorial effects. The different arrangements in the plan and some common characteristics among the typologies allowed us to propose some relevant observations.

By analyzing the diagram, for each typology can be highlighted in the following aspects:

- Tulou (green): the three projects had limited difference in terms of results, highlighting that the regeneration projects of this type were clearly thought out according to the effects they must produce in the area.
- Cascina (blue): similar to the Tulou projects, even those of the farmhouses had a fairly limited difference in terms of territorial results. This can be dictated by the fact that these projects usually have a fairly common goal or are limited by the characteristics of local regulations.
- Hacienda (yellow): it was evident that two of the three projects have fairly low evaluations with reference to the SDGs. In particular, for some characteristics of projects that were mainly aimed at the private sector, no benefits of sustainable impact for the territory were highlighted.
- Marae (red): even in the case of the Marae, the three projects were positioned quite far from each other, showing how the impacts on the territory were of different elements still alive in today's New Zealand society (it meant that the impacts they have on the territory can vary a lot).

In general, from the areas as they are presented in Figure 8 are defined by the connected points of each project per typology, we can read two main tendencies namely clustered tendencies, and spread tendencies:

- clustered (Tulou and Cascina): the differences between the results were quite limited. This can be dictated by the fact that the projects were designed with a similar objective in terms of territorial impact and that in Italy and China there are quite restricted regulations or design codes that force the projects to have similar and basically good results.
- spread (Hacienda and Marae): the variety of results between the projects depended on the fact that the buildings take on more varied functions so that they had different effects on the territory.

These tendencies showed how the regeneration projects of Tulou and Cascina had general common effects on sustainable territorial development. In these cases, the projects gave rise to fairly homogeneous (and sustainable) territorial effects. It would be interesting to analyze, in the subsequent development of the research to what factor this trend is due to the Italian legislative restrictions in terms of regeneration of the patrimony or to the strong Chinese government control.

On the contrary, the projects of Marae and Hacienda, with a wider area among the projects, presented a more varied effect on the territories, with results that were definitely less sustainable than Tulou and Cascina.

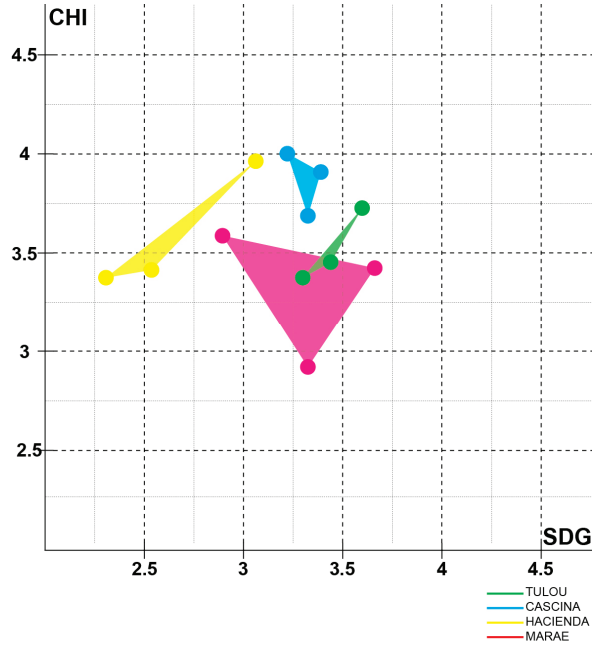


Figure 8. Territorial Impacts of the different typologies (Tulou is green; Cascina is blue; Hacienda is yellow; Marae is red) located in a diagram defined by the Sustainable Development Goals (SDGs) and the Cultural Heritage Indicators (CHIs).

3.1.2. Relation among Typologies, and Single Indicators of SDGs and CHI

The results presented in this following Figure 9 are the averages of each typology, with the eight CHIs parameters and the seven SDGs taken into consideration. These radar charts allowed us to visually highlight some of the tendencies and characteristics of the regeneration projects for each typology. The most significant results are discussed below.

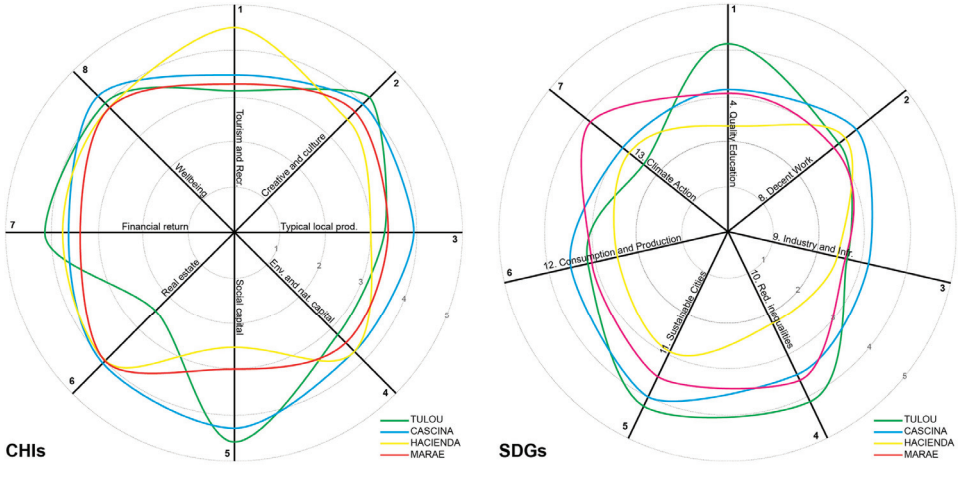


Figure 9. This figure represents results of the Experts Interview, expressed by radars, associating the projects of the four typologies to the CHIs (**left**) and the SDGs (**right**).

Observing the Cultural Heritage Indicators (CHI) radar, it can be highlighted that, in general, the typologies had relatively uniform behaviors. In fact, the lines overlapped for most of the circle. However, precisely this overlapping highlighted some relevant aspects. While Tulou (green), Cascina (blue), and Marae (red) had relatively low values for the first indicator of Tourism and Recreational Activities, the Hacienda (yellow) regeneration projects showed a clearly higher value, showing how the tourism sector was a strong impetus of regeneration in the Mexican context. On the contrary, it emerged quite visibly from the CHI radar that, at the same time, Hacienda and Marae show limited impact in terms of CHI indicator 5 "social capital". For the Hacienda, this aspect clearly confirmed how the impact of tourism in the social sector was still problematic and a not fully resolved issue. On the other hand, this low value for the Marae, which traditionally represented the symbol of the community itself, represented how, according to the experts, contemporary regeneration projects of Marae buildings have partially lost the ability to positively impact on social capital. This value indicated that both Haciendas and Maraes communities should implement social cohesion along with collaborative economy initiatives in order to improve their social capital in terms of physical and intangible capitals. Yet, this value was, at least, less impactful than the regeneration projects of the Cascina and Tulou.

Another specific aspect that emerged from the CHI radar was the indicator 6, "Real Estate", which was very irrelevant in the Tulou projects. This aspect can undoubtedly be related to the Chinese reality, where these kinds of projects are mainly managed and promoted by the government, who considers these interventions as opportunities to compensate the local population for the heavy influence that rural and urban development is impacting territories and societies.

There is, moreover, an interesting characteristic that deserves to be underlined for the regeneration projects of Cascina (blue). CHI indicator 3, which was related to Typical Local Production, highlighted how these projects were often indeed related to the initiatives for the production of goods and services, in total alignment with the original functions of the Cascina typology, and with the orientation provided by EU priorities through rural development programs.

On the other side, if we focus on the Sustainable Development Goals (SDG) radar, the situation was a little more multifaceted and could be immediately perceived by the separation between the four lines of typologies, which were more outdistanced than the CHIs lines. In the SDGs diagram, it emerged immediately that the yellow line of the Hacienda projects was almost always the most central line. That means it was the one that showed the least values for the SDGs, representing low sustainable impacts on the territories. In particular, this was evident for Goal 10—Reduced Inequalities (Indicator 4), which also refers to the aspect highlighted in the previous diagram of CHIs for indicator 5, Social Capital. This does not mean that the regeneration projects of Haciendas are not sustainable as a whole but it means that the efficiency in terms of social sustainability for the Hacienda regeneration projects needs to be implemented in terms of ability to positively impact on social capital.

Another relevant result showed in the SDGs radar was that the Cascina (blue) and Tulou (green) regeneration projects tend to show the best values, placing themselves almost always among the outermost lines. It is interesting to relate this observation with those coming from the CHIs' diagram: the projects of Cascina and Tulou had, respectively, similar outputs in terms of territorial impacts, and both had good results in terms of sustainable impacts, albeit the great existing economical, social, and governmental differences [51].

As for Marae (red), it had behavior quite similar to that of Cascina and Tulou, showing quite positive values in terms of sustainable impacts. However, it is interesting to highlight how the attitude of the Marae regeneration projects stands out regarding Goal 13—Climate Action (Indicator 7). This issue is very intriguing and opens up interesting reflections for future research, because the Marae, as a typology, is based on a strong relationship with the environment: the orientation towards orography and natural resources are the basis of this typology which, although rigid in its spatial organization, knows how to adapt very well to the natural context. It would be interesting, in fact, to study whether this traditional characteristic can influence even the contemporary regeneration projects so deeply that this feature can appear today as a positive impact on the territory, in terms of climate action. Moreover,

next to this consideration, the attention of New Zealand regulations in terms of climate action can be considered as a relevant aspect.

4. Discussion and Conclusions

The research highlights several aspects that should be discussed, both in terms of methodology and contents.

In terms of methodology, this study offers numerous confirmations that the application of the Expert Interview methodology works well with this project. For instance, the validation of phenomena emerges in the well-known problematic relationship between tourism and social impact, and the role of the Chinese government in controlling regeneration initiatives among many others as earlier described. Furthermore, the scope of application for the expert interview method is much broader and deeper than many other research procedures. Even though it has been applied in several fields of studies, it has seldom been applied in architectural and urban studies research. Hence, with this paper, it is possible to affirm that this methodology can be fruitfully used as a self-sufficient method as well as in the architectural-urban studies with the aim to analyze and interpret contemporary phenomena of various territories. For example, it can be applied for the study of and to understand how the regeneration of ancient community buildings impact the sustainable development of the local context in terms of culture and identity. This method is effective in our research because it allowed collecting unknown and/or more reliable information/insight not so evident during our investigation. As to say, significant results can be achieved when authoritative opinions and professional estimations relating to the research are taken from persons whose competence is proved and not questioned. Due to the fact that respondents in the expert interviews are highly qualified in the investigated area, it often eliminates the need for additional verification procedures.

As Meuser, Nagel, and Libakova, and Sertakova [37,39] affirmed, the application of the expert interviews allows access to information that gives an opportunity to create a holistic view of the significance of SGDs and CHIs impact on the process of regeneration territories and shared-living buildings heritage.

In terms of content and related to the research question, this study reveals that the regeneration of historic community buildings often brings a change in the relationship with the context. From the state of introversion toward the landscape of these historical buildings, the regenerated buildings become extroverts, generators of social relationships, promoters of activities, and local life; in other words, sustainable regeneration of heritage allows to re-create a community. Thanks to these changes, this research shows how the urban-architectural regeneration of these historical typologies can be clearly associated with indications of sustainable development. In fact, these projects can be related to indicators of sustainable development for the territory, but in particular with the enhancement of architectural heritage. Of course, it is necessary to underline once more that there are differences between typologies. Some show more sustainable impact than others and some show more uniformity in the results. This opens up some more questions: the fact that some typologies i.e., Cascina and Tulou can be considered as "best practices" is due to the drivers of the context such as local laws, market, cultural sensibility, or characteristics typical of the typology? For Cascina and Tulou, does the fact that uniformity of results is associated with more sustainable practices mean that controlling results also lead to sustainable practices?

So, without any doubt, investments must be made in the recovery of the existing architectural heritage, in particular of that heritage which is characterized by being a symbol of local housing culture often associated with shared forms of living. These projects of Shared Living Heritage (SLH) continue to be an element of valorization of local communities and an actor promoting the sustainable development of territories.

To some extent, it is clear that normative and superordinate design actions need to be adopted for the sustainable development of territories without compromising the freedom of creativity and the use of natural resources and participation of local communities (Figure 10).

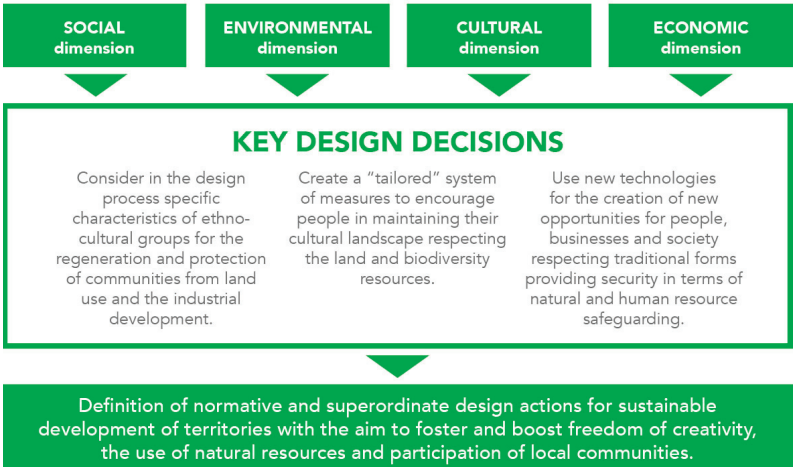


Figure 10. Key design decisions for the regeneration of shared-living heritage.

With this study, we also tried to demonstrate an approach to democratize the heritage regeneration process design approach and to preserve the identities of communities by, for example, looking at city development, real estate market, and sometimes the unavoidable slowness of local governments to cope with necessary changes. Thus, it is necessary to enhance the skills and awareness of communities in the field of sustainability, culture, and traditions in order to take into account during the design process the specific characteristics of ethnocultural groups for the regeneration and protection of communities from land use and the industrial development.

In the area of shared-living heritage, it is necessary to develop a series of measures so that the communities could foster and thrive their culture and products. By creating sustainable business opportunities through regeneration and being self-sustained, this will help to build a balance between governments top-down approaches and citizen bottom-up engagement. Alongside this, policymakers along with designers, citizens' representatives, and stakeholders need to create a "tailored" system of measures to encourage people to maintain and steward their cultural landscape respecting the land and biodiversity resources. Moreover, it is still necessary to provide sustainable perspectives in terms of living conditions, work opportunities, housing, services to the locals, engaging in innovative models of growth within traditional economic, and working activities. In this regard, new technologies, such as the internet of things, 5G telecommunication, new mobility models, new transportation services by drones and other devices, etc., are creating new opportunities for people, businesses, and society in remote places respecting traditional forms providing security in terms of natural and human resource safeguarding. In other words, it is necessary to cooperate to create resilient, sustainable, and prosperous communities.

Once these issues have been outlined by this work, the following steps for the research can be directed toward a better understanding of the reasons why some typologies have better and more uniform behavior in terms of territorial sustainability. A deeper analysis, able to support the definition of guidelines for governments, associations, entrepreneurs, and citizens can be relevant to understand how to realize (with public policies or design strategies) regenerative interventions, so as to improve and maximize the benefits in terms of sustainable impacts on territories.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The narrative descriptions of the projects.

Appendix.A.1. Cascina

Cascina Cuccagna (2011); Milan, Italy; Associazione Consorzio Cantiere Cuccagna (ACCC): Changing its role from agriculture to a place of culture and meeting, and after years of neglect, this project becomes an oasis to socialize within the urban grid of Milan that seeks to improve the lives of its residents. Exhibitions, culture, culinary activities are activities that are sought to be developed in this Cascina that refuses to disappear, generating a new identity more in keeping with its current reality.

Co-Housing Chiaravalle (2016); Milan, Italy; Cohousing.it: Creating community is the objective of this recovery project for a Cascina from the 8th century. Surrounded by large garden areas and spaces to promote common activities among residents, this project is friendly to the environment using renewable energy. Between history and a modern lifestyle, this set of 50 houses offers the possibility of generating a change in the lives of their owners.

Cascina Roccafranca (2007); Turin, Italy; Turin's University, ANCI, and Foundation Cascina: This project is based on regulations that promote collaboration between citizens and government institutions and seeks to regenerate numerous abandoned industrial buildings. Located in a city with experience in regeneration and redevelopment such as Turin, it seeks through this intervention to use buildings and vacant lots to fight against the social exclusion of the residents of these neighborhoods, generating social enterprises and centers for community participation, in order to reduce poverty, unemployment and create a space for coexistence. Thanks to various financing programs, to which the city has been credited, it is that projects like this can be carried out.

Appendix.A.2. Hacienda

Hacienda Niop (2014), Campeche, Mexico; R79 + AS ARQUITECTURA: The balance between the history of a hacienda and a new use that offers a resting space for its visitors results in this Boutique Hotel project in an old abandoned hacienda in southern Mexico. The need for new uses to their spaces, in accordance with a new identity and respect for the essence of the original buildings and exterior spaces, guide this project to ensure that they coexist despite their contrasting times and uses.

Hacienda San Pedro Celso Garza Guajardo (1990); Nuevo Leon, Mexico; Autonomous University of Nuevo León: This project recovers a 17th-century hacienda for the creation of a center that exhibits regional history. This center has a library, museum, exhibition rooms that at the same time function as a space for workshops and meetings, as well as an open-air theater. Managed by a public university, this project allows the use of some of its areas for institutional activities, educational or cultural activities for the entire public.

Hacienda San Antonio Chablé (2017); Chocholá, Yucatan, Mexico; Central de Proyectos SCP: Restoring a 19th-century hacienda and turning it into a hotel, the spaces were adapted for their new activities. Some spaces were decided to be intervened, and very interesting spaces were created, mixing the old and the new. The recovery of this space also contemplated the natural landscape, mainly the flows that fed a cenote, which is the heart of the project. In other spaces that had become ruins, they were left intact as a reminder of the relentless passage of time.

Appendix.A.3. Tulou

Tulou renovation project (2019); Fujian, China; Rural Urban Framework + University of Hong Kong: A collaboration between Rural Urban Framework and University of Hong Kong has given Tulou Zhenchunlou two buildings that provide the community with spaces for coexistence and recreation. Being Zhenchunlou, the first Tolou to appear in the village of Lantian, China, was abandoned for decades until the intervention by Rural Urban Framework. Made of wood, combining ancient and modern techniques, these structures, a tower and a trumpet, which is born in a first-level window and opens until it ends up resting in a patio, forming some bleachers. They have become part of daily life for the inhabitants of the community by developing activities such as study, coexistence, or the presentation of events.

School Bridge (2009); Fujian, China; Li Xiaodong Atelier: More than just satisfying the need to cross a river, this project pushes functionality to the limit by not only giving the community a connection between the two ends of a river, but also a school, a library and a store. It is also an attraction for the elderly and children to spend time on it. Located in the town of Hakka Xiashi, Fujian province in China, this project can become the key to revitalize this town that was facing aging and neglect of its inhabitants. An example of collaboration between designers and users to achieve a multi-functional project in harmony with its surroundings and its history.

Community-led design in China (2018); Fujian, China; AzuKo + Hello Shenzhen: five examples of participatory design projects. Cha'er Hutong Children's Library and Art Center in Beijing, Xihe Village Cooperative in Henan Province, Angdong Health Center in Hunan Province, and the Hada Village Water Community Center and Taoshu Tulou, both in Fujian province. These projects by Azuko (an architectural charity serving disadvantaged communities) show us a design led by the community for a humanitarian impact and the development of these communities. A design methodology, such as the one used, focused less on the economic and more on the human helps to achieve the objective of a local vision and appropriation of the project, taking into account the strengths of the community and disregarding its problems or differences, to achieve a solid project that meets the expectations of all participants and users.

Appendix.A.4. Marae

Te Noho Kotahitanga Marae (2012); Albert campus, New Zealand; Lyonel Grant: This Marae, located at the New Zealand University of Technology, is a spiritual place built in a sustainable way and combines the tradition with a contemporary environmental sensitivity. Its main function is to gather people for ceremonial services and celebrations, and also it is a repository of regional historical knowledge. This project is complemented by a dining room for 200 people. Since the concept, this project has shown the spirituality necessary for the functions it was designed for.

Tanatana Marae (2019); Waimana, New Zealand; Apa Architects: Project designed for a community with the ceremonial function of living in mourning for a deceased relative. This duel lasts three days and all his relatives accompany the body in this building that is complemented by another nearby construction in which the family's valuable objects are stored. It also has sustainable elements for water reuse, light sensors, thermal materials, and self-sufficient waste disposal. It has all the necessary services to become a space to remember the family member who has left, rest with him, and being with him in his last moments in this life.

Pehiáweri Marae (1980); Glenbervle, Whangarel, New Zealand; Ongoing regional regeneration project: This research project seeks to address the problem of homelessness for Maori people through the collaborative design together with the community, so they are involved in the entire design process. The project contemplates groups of houses of different characteristics with the necessary flexibility to allow community life and, at the same time, maintain the privacy of each family.

Appendix B

Experts' names and a short description of their background:

Expert #01—Roberto Cárdenas Martinez—Professor at the Universidad Tecnológica de México S.C. Expert in the conservation of the architectural heritage. Professor Cárdenas has also experience in the Italian context having spent a period of research and teaching at the Università degli Studi di Napoli Federico II

Expert #02—Enrico Valentino Hernández—Lecturer at the Tecnologico de Monterrey, College of Architecture, Arts and Design. Chair of the 3ME Arquitectura in Guanajuato Mexico. Their expertise comes from the development of projects around traditional 18th-century buildings of Central Mexico. Rehabilitation of historic places and the preservation of cultural landscapes is their main focus.

Expert #03—Gregorio de la Rosa—Lecturer at Tecnologico de Monterrey, College of Architecture, Arts and Design. He is an expert in the historic preservation of 16th-century architecture, particularly religious and recreational buildings. He has over 30 years of experience in preservation projects in Central and Southern Mexico. He is a consultant at Instituto Nacional de Antropología e Historia at the regional and national levels.

Expert #04—Sara Broglio—PhD, Senior Structural Engineer, and leading specialist in resilient structural systems at Aurecon, Canterbury, New Zealand. Dr. Sara Broglio has experience in both Italy and New Zealand involved in a series of academic activities including research, laboratory classes on structural regeneration of historical buildings. In particular, being a young professional she is active in community engagement and social projects in West Coast, New Zealand.

Expert #05—Angelo Bugatti—Advisory professor at Tongji University, Shanghai, China, and former professor in architecture and urban design in Italy. Professor Angelo Bugatti has over 30 years of experience in research, teaching, and design in Italy, China, and Central America including Mexico. Director of the 15 editions of the International Design Seminar "Urban Culture and Landscape Renewal", he was the coordinator for Scientific Agreements between the University of Pavia, the Universidad Federal da Bahia, and the Universidad Central Santiago del Chile and the Tongji University of Shanghai.

Expert #06—Aldo Castellano—Professor of history of architecture at the Politecnico di Milano, Italy. He has 40 years of academic activities. He was also: founder and vice president of the Italian Society for Industrial Archeology, (1975–1980); deputy editor of L'Arca magazine, (1986–1991); director of the Architecture section of the Bompiani Dictionary (1987); founder and vice president of RURAL_IA Onlus (1998–2000); member of the Commission for the landscape of the Municipality of Milan (2009–2012). He has carried out, and continues to carry out, studies and research with publications on the problems of conservation and reuse of cultural heritage.

Expert #07—Eugenio Mangi—PhD, Assistant professor at the Department of Architecture and Built Environment, The University of Nottingham, Ningbo China. Dr. Mangi has over 10 years of experience in China, both in academia and in practice, being a researcher and co-founder of the firm Draftarch realizing several projects in China. The participation in the design process of the local communities is the core of his activities for the regeneration and conservation of architecture and heritage buildings.

Expert #08—Minqing Ni—PhD, Lecturer in environmental design at College of Design and Innovation, Tongji University, Shanghai, China. Executive Director/Coordinator of the Tongji DESIS Lab (Design for Social Innovation and Sustainability). She is an active designer and researcher. Her activities focus on the topic "Design intervention based social innovation" exploring possible actions linking the sustainable and ecological lifestyle of communities and understanding of the relationship between the social and the public space.

Expert #09—Dan Zhu—Architect, Executive manager of the @Design Square of Tongji University. Graduated in Architecture in USA at the University of Cincinnati College of Design, Architecture, Art, and Planning. In Shanghai, she is well recognized by the civic society as a leading specialist in sustainable design and organizer of scientific meetings and public meetings for the study and dissemination of sustainable culture in China and America.

Expert #10—Elisabetta Venco—PhD, Researcher/Assistant professor in urban planning and sustainability, Department of Civil Engineering and Architecture, University of Pavia, Italy. Dr. Venco is a young researcher with significant researches carried on methodological approaches to improve the development of the Rural-urban context focusing on urban approaches to analyze and enhance cultural heritages' contexts.

Expert #11—Caterina Pietra—PhD, Candidate in design, modeling, and simulation in engineering at the Department of Civil Engineering and Architecture, University of Pavia, Italy. Thanks to her study experience between China and Italy, in 2018 she got a Double Master Degree in Building Engineering and Architecture from Pavia University and Tongji University in Shanghai on the topic of "Heritage Conservation and Urban Regeneration in China". In 2019 she was a visiting researcher at the College of Design and Innovation of Tongji University. In Italy, she is involved in several citizens' groups' activities in rural areas of Lombardy.

Appendix C

The following table represents the values from the Expert Review.

	HERITAGE								SDG						
	Tourism and Recreation	Creative, cultural and innovative activities	Typical local productions	Environment and natural capital	Social capital/cohesion and inclusion	Real estate and Financial return	Cultural value of properties/ landscape	Wellbeing	SDG 4 Quality Education	SDG 8 Decent Work and Economic Growth	SDG 9 Industry, Innovation and Infrastructure	SDG 10 Reduced Inequalities	SDG 11 Sustainable Cities and Communities	SDG 12 Responsible Consumption and Production	SDG 13 Climate Action
AVERAGE	3.6	3.8	3.3	3.5	3.8	3.4	3.7	3.8	3.1	3.2	2.7	3.2	3.6	3.2	2.8
TOTAL	3.6								3.1						
	3.4														

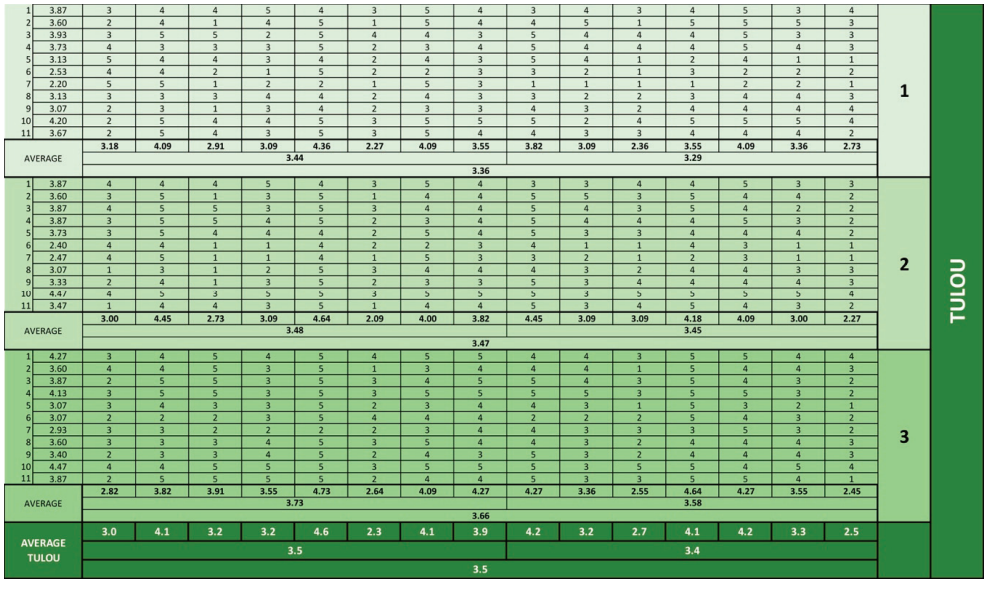
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4	4.00	3	5	5	4	5	2	3	5	5	3	3	4	5	5	3		
5	2.67	3	4	3	2	4	3	2	3	2	3	3	2	3	2	1		
6	3.67	4	4	4	4	4	4	4	4	3	3	3	3	4	4	3		
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9	2.73	3	3	3	3	4	4	3	3	2	3	1	2	3	3	1		
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AVERAGE		4.09	4.27	4.18	3.82	4.18	3.82	3.55	4.09	3.00	3.64	2.64	3.09	3.82	3.73	2.64		
		4.00								3.22								
		3.61																
1	3.20	3	4	3	3	3	4	3	3	4	2	4	3	2	3	4	2	
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AVERAGE		2.00	3.09	3.91	4.00	4.00	4.27	3.82	4.09	2.55	3.18	2.82	3.09	4.18	3.73	3.73		
		3.65								3.32								
		3.49																
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11	3.20	4	4	3	3	4	5	2	3	4	3	3	2	3	3	2		
AVERAGE		4.36	4.18	3.36	3.27	4.55	4.09	3.27	3.91	3.64	3.73	3.27	3.55	3.82	3.18	2.45		
		3.88								3.38								
		3.63																
AVERAGE CASCINA		3.5	3.8	3.8	3.7	4.2	4.1	3.5	4.0	3.1	3.5	2.9	3.2	3.9	3.5	2.9		
		3.8								3.3								
		3.6																

1	3.20	5	2	2	3	1	5	4	4	3	4	3	3	2	3	4		
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AVERAGE		**4.82**	**2.73**	**2.55**	**3.36**	**1.82**	**4.36**	**3.64**	**4.09**	**1.64**	**3.45**	**2.82**	**2.00**	**2.45**	**2.55**	**2.73**		
		3.42								**2.52**								
		2.97																
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AVERAGE		**4.18**	**4.27**	**3.36**	**4.09**	**4.00**	**3.45**	**4.36**	**3.73**	**3.55**	**3.18**	**2.36**	**3.09**	**3.45**	**3.09**	**2.73**		
		3.93								**3.06**								
		3.50																
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10	4.00	5	5	4	5	5	3	3	4	4	4	4	4	3	3	4		
11	2.87	5	3	2	3	2	4	3	4	3	3	3	1	3	2	2		
AVERAGE		**4.82**	**2.91**	**3.09**	**3.64**	**1.82**	**4.09**	**3.09**	**3.45**	**1.64**	**2.91**	**2.27**	**1.55**	**2.55**	**2.36**	**2.82**		
		3.36								**2.30**								
		2.83																
AVERAGE HACIENDA		**4.6**	**3.3**	**3.0**	**3.7**	**2.5**	**4.0**	**3.7**	**3.8**	**2.3**	**3.2**	**2.5**	**2.2**	**2.8**	**2.7**	**2.8**		
		3.6								**2.6**								
		3.1																

HACIENDA

1	3.67	3	3	2	4	3	4	5	4	4	4	5	3	4	3	4		
2	3.80	2	3	4	5	5	3	5	4	4	4	2	4	4	4	4		
3	3.27	4	4	3	3	5	1	4	1	4	2	2	5	5	4	2		
4	3.07	4	4	3	2	4	3	3	3	4	3	1	4	3	3	2		
5	3.67	3	5	4	4	5	2	4	3	5	3	3	4	4	3	3		
6	3.07	5	5	5	4	4	2	3	2	3	2	2	3	2	2	2		
7	2.93	4	4	3	3	3	3	4	4	4	4	2	3	1	1	1		
8	3.80	3	3	3	5	5	3	3	4	4	3	4	4	4	5	4		1
9	3.20	2	4	1	4	5	3	1	4	5	3	2	5	4	3	2		
10	4.40	5	5	5	5	5	4	4	4	4	4	5	4	4	4	4		
11	3.93	4	5	3	5	4	4	5	5	4	3	3	3	4	4	3		
AVERAGE		**3.55**	**4.09**	**3.27**	**4.00**	**4.36**	**2.91**	**3.73**	**3.45**	**4.09**	**3.18**	**2.82**	**3.82**	**3.55**	**3.27**	**2.82**		
		3.67								**3.36**								
		3.52																
1	3.67	2	3	4	5	4	2	5	4	4	3	3	4	4	4	4		
2	3.80	4	5	4	3	5	4	4	4	4	4	1	3	5	4	3		
3	2.87	3	3	5	2	4	2	4	1	2	2	3	4	3	2	3		
4	3.00	3	3	2	2	4	3	2	4	4	3	2	4	4	3	2		
5	3.67	3	5	4	4	5	2	5	4	3	3	3	5	4	2	3		
6	2.67	3	4	3	3	3	3	3	2	2	2	2	3	3	2	2		
7	2.20	1	4	1	3	4	3	4	4	2	1	1	2	1	1	1		
8	3.27	2	3	2	3	4	3	4	4	3	2	2	4	4	5	4		2
9	1.73	2	2	3	1	1	5	1	1	1	1	1	1	1	1	2		
10	3.93	4	5	4	4	3	4	4	4	4	4	4	4	3	4	4		
11	3.33	3	3	3	2	5	4	3	4	3	3	3	4	4	3	3		
AVERAGE		**2.73**	**3.64**	**3.18**	**2.91**	**3.82**	**3.18**	**3.55**	**3.27**	**2.91**	**2.55**	**2.27**	**3.45**	**3.27**	**3.00**	**2.82**		
		3.28								**2.90**								
		3.09																
1	3.67	3	4	3	5	4	3	5	4	3	3	3	3	4	4	4		
2	3.33	4	5	2	3	4	5	3	3	3	3	2	3	4	4	2		
3	3.20	4	4	4	2	4	5	3	3	1	2	3	3	3	3	4		
4	3.20	4	3	4	3	3	5	3	4	1	3	2	2	4	4	3		
5	3.13	2	3	4	4	4	3	4	4	2	3	2	3	4	2	3		
6	2.73	2	3	2	3	4	4	2	3	3	4	2	3	2	2	2		
7	3.47	5	5	5	4	5	4	4	4	1	3	4	2	3	2	1		
8	3.67	2	3	3	4	5	4	4	5	3	3	3	4	4	4	4		3
9	2.27	2	1	1	2	3	5	2	3	1	1	1	2	3	4	3		
10	4.20	4	5	5	5	4	4	4	5	4	5	5	3	3	3	4		
11	2.93	4	3	3	2	3	3	3	4	2	2	2	4	4	3	2		
AVERAGE		**3.27**	**3.55**	**3.27**	**3.36**	**3.91**	**4.09**	**3.36**	**3.82**	**2.18**	**2.91**	**2.64**	**2.91**	**3.45**	**3.18**	**2.91**		
		3.58								**2.88**								
		3.23																
AVERAGE MARAE		3.2	3.8	3.2	3.4	4.0	3.4	3.5	3.5	3.1	2.9	2.6	3.4	3.4	3.2	2.8		
		3.5								3.0								
		3.3																

MARAE



References

1. Brebbia, C.A.; Galiano-Garrigos, A. *Urban Regeneration & Sustainability*; WIT Press: Southampton, UK, 2017.
2. Girardet, H. Sustainability is unhelpful: We need to think about regeneration. Available online: https://www.theguardian.com/sustainable-business/blog/sustainability-unhelpful-think-regeneration (accessed on 2 June 2020).
3. Kamrowska-Załuska, D.; Obracht-Prondzyńska, H. Urban regeneration in urban functional areas in Poland as an instrument of implementation of the EU Cohesion Policy. *Growth Chang.* **2020**, *51*, 278–301. [CrossRef]
4. Li, X.; Zhang, F.; Chi, E.; Wei Lan, H. Collaborative workshop and community participation: A new approach to urban regeneration in China. *Cities* **2020**, *102*, 102743. [CrossRef]
5. Grijalba, O.; Urrutia, N.; Eizaguirre-Iribar, A.; Irulegi, O.; Hernández, R. Impact of the Public Management Model on the Implementation of Urban Regeneration Policies: Evidence of the Case of the Basque Country, Spain. *Plan. Pract. Res.* **2020**, *35*, 302–319. [CrossRef]
6. Azadeh, L.; Mahdi, G.; Timothy, J. Urban regeneration through heritage tourism: Cultural policies and strategic management. *J. Tour. Cult. Chang.* **2019**, 1–18. [CrossRef]
7. Wang, Y.; Bramwell, B. Heritage protection and tourism development priorities in Hangzhou, China: A political economy and governance perspective. *Tour. Manag.* **2012**, *33*, 988–998. [CrossRef]
8. Güzey, O. The last round in restructuring the city: Urban regeneration becomes a state policy of disaster prevention in Turkey. *Cities* **2016**, *50*, 40–53. [CrossRef]
9. Ghada, K.; Tarek, I. Urban Regeneration Challenges of Heritage Cities Using GIS (Luxor City Case Study). In Proceedings of the 1st International Conference on Towards a Better Quality of Life, El-Gouna, Egypt, 24 November 2017; pp. 1–12.
10. Serrano–Jiménez, A.; Lima, M.L.; Molina–Huelva, M.; Barrios-Padura, A. Promoting urban regeneration and aging in place: APRAM—An interdisciplinary method to support decision-making in building renovation. *Sustain. Cities Soc.* **2019**, *47*, 101505. [CrossRef]
11. Della Spina, L.; Lorè, I.; Scrivo, R.; Viglianisi, A. An Integrated Assessment Approach as a Decision Support System for Urban Planning and Urban Regeneration Policies. *Buildings* **2017**, *7*, 85. [CrossRef]
12. Giorgi, E. Sharing as Cultural Preexistence. In *The Co-Housing Phenomenon. Environmental Alliance in Time of Changes*; Giorgi, E., Ed.; Springer Nature: Cham, Switzerland, 2020; pp. 59–91.

13. Cattaneo, T.; Giorgi, E.; Ni, M. Landscape, Architecture and Environmental Regeneration: A Research by Design Approach for Inclusive Tourism in a Rural Village in China. *Sustainability* **2019**, *11*, 128. [CrossRef]
14. Bastian, O.; Grunewald, K.; Syrbe, R.U.; Walz, U.; Wende, W. Landscape services: The concept and its practical relevance. *Landsc. Educ.* **2014**, *29*, 1463–1479. [CrossRef]
15. Walz, U. Landscape structure, landscape metrics and biodiversity. *Living Rev. Landsc. Res.* **2011**, *5*, 35. [CrossRef]
16. Bastian, O.; Walz, U.; Decker, A. Historical landscape elements: Part of our cultural heritage—A methodological study from Saxony. In *The Carpathians: Integrating Nature and Society towards Sustainability*; Kozak, J., Ostapowicz, K., Bytnerowicz, A., Wyzga, B., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 441–460.
17. Termorshuizen, J.W.; Opdam, P. Landscape services as a bridge between landscape ecology and sustainable development. *Landsc. Ecuc.* **2009**, *24*, 1037–1052. [CrossRef]
18. Cattaneo, T.; De Lotto, R. *Rural–Urbanism Architecture. Design Strategies for Small Towns' Development*; Alinea Editore: Firenze, Italy, 2015.
19. Cattaneo, T.; Sha, Y.; Ji, Y. Architectural design strategies for the rural development in Europe. In *Urban Architecture (UA)*; Heilongjiang Science and Technology Press: Harbin, China, 2015; pp. 109–111.
20. Cloke, P. Counterurbanisation: A Rural Perspective. *Geography* **1985**, *70*, 13–23.
21. Phillips, M. Counterurbanization and Rural Gentrification: An Exploration of the Terms. *Popul. Space Place* **2010**, *16*, 539–558.
22. Karsten, L. Counterurbanisation: Why settled families move out of the city. *J. Hous. Built Environ.* **2020**, *35*, 429–442. [CrossRef]
23. Brown, J.; Hay-Edie, T. *Engaging Local Communities in Stewardship of World Heritage: A Methodology Based on the COMPACT Experience*; UNESCO World Heritage Centre: Paris, France, 2014.
24. Paganoni, M. Reclaming heritage for UNESCO: Discursive Practices and Community Building in Northern Italy. In *Making Publics, Making Places*; Griffiths, M., Ed.; The University of Adelaide Press: Adelaide, Australia, 2016; pp. 75–94.
25. Maeer, G. The Values and Benefits of Heritage: Do economists think more than money? *APT Bull. J. Preserv. Tecnol.* **2014**, *45*, 57–63.
26. Jarvis, H.; Bonnett, A. Progressive Nostalgia in novel living arrangements: A counterpoint to neotraditional new urbanism? *Urban Stud.* **2013**, *50*, 2349–2370. [CrossRef]
27. Zukin, S. *Naked City: The Death and Life of Authentic Urban Places*; Oxford University Press: Oxford, UK, 2010.
28. Rodwell, D. Managing change in historic urban landscape. *Context* **2007**, *3*, 1.
29. United Nations Educational, Scientific and Cultural Organisation. *The UNESCO Recommendation on the Historic Urban Landscape*; UNESCO World Heritage Centre: Paris, France, 2019.
30. Araoz, G. World-Heritage Historic Urban Landscapes: Defining and protecting authenticity. *J. Preserv. Technol.* **2008**, *39*, 33–37.
31. Elefante, C. The Greenest Building Is One That Is Already Built. *Forum J.* **2007**, *21*, 26–38.
32. Fromm, D. Seeding Community: Collaborative Housing as a Strategy for Social and Neighborhood repair. *Built Environ.* **2012**, *38*, 364–394. [CrossRef]
33. Milliken, W. The Yanomami Are Great Observers of Nature. Survival International. Available online: https://www.survivalinternational.org/articles/3162-yanomami-botanicalknowledge (accessed on 15 May 2020).
34. Hill, J.; Woodland, W. Subterranean settlements in Southern Tunisia: Environmental and cultural controls on morphology, community dynamics and sustainability. *Geography* **2003**, *88*, 23–39.
35. Umali, S. Repackaging "traditional" architecture of the African Village in Zimbabwe. Urban and architectural heritage conservation within sustainability. In *Urban and Architectural Heritage Conservation within Sustainability*; Hmood, K., Ed.; Intechopen: London, UK, 2018.
36. Groat, L.N.; Wang, D. *Architectural Research Methods*, 2nd ed.; Wiley: Hoboken, NJ, USA, 2013.
37. Meuser, M.; Nagel, U. The Expert Interview and Changes in Knowledge Production. In *Interviewing Experts. Research Methods Series*; Bogner, A., Littig, B., Menz, W., Eds.; Palgrave Macmillan: London, UK, 2009; pp. 17–42.
38. Bogner, A.; Menz, W. The Theory-Generating Expert Interview: Epistemological Interest, Forms of Knowledge, Interaction. In *Interviewing Experts. Research Methods Series*; Bogner, A., Littig, B., Menz, W., Eds.; Palgrave Macmillan: London, UK, 2009; pp. 43–80.
39. Libakova, N.M.; Sertakova, E.A. The Method of Expert Interview as an Effective Research Procedure of Studying the Indigenous Peoples of the North. *J. Sib. Fed. Univ. Humanit. Soc. Sci.* **2015**, *1*, 114–129. [CrossRef]

40. Giorgi, E. *The Co-Housing Phenomenon: Environmental Alliance in Time of Changes*; Springer Nature: Cham, Switzerland, 2020.
41. Wang, S.-S.; Li, S.-Y.; Liao, S.-J. The Genes of Tulou: A Study on the Preservation and Sustainable Development of Tulou. *Sustainability* **2012**, *4*, 3377–3386. [CrossRef]
42. Crotti, S.; Bertelli, G.; Reggio, M.; Vanetti, D. *Abaco Degli Edifici nel Parco del Ticino*; Alinea Editrice: Firenze, Italy, 2008; pp. 12–31.
43. Van Zantwijk, R. *The Aztec Arrangement. The Social History of Pre-Spanish Mexico*; University of Oklahoma Press: Norman, OK, USA, 1985.
44. Tapsell, P. Marae and tribal identity in urban Aotearoa/New Zealand. *Pac. Stud.* **2002**, *25*, 141–171.
45. Kawharu, M. Environment as a Marae locale. In *Kaitiaki: Maori and the Environment*; Selby, R., Moore, P., Mulholland, M., Eds.; Huia: Wellington, New Zealand, 2010; pp. 221–239.
46. Cattaneo, T.; Giorgi, E.; Flores, M.; Barquero, V. Booklet for Expert Interview. Territorial effects of shared-living heritage regeneration. Available online: https://www.dropbox.com/s/tp6tuhetr9u8r8z/Expert%20Interview_booklet.pdf?dl=0] (accessed on 15 September 2020).
47. Nocca, F. The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool. *Sustainability* **2017**, *9*, 1882. [CrossRef]
48. United Nations. General Assembly UN (2015) Resolution Adopted by the General Assembly on 25 September 2015. Transforming our World: The 2030 Agenda for Sustainable Development. Available online: https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf (accessed on 26 June 2018).
49. Giorgi, E.; Cattaneo, T.; Ni, M.; Enríquez Alatriste, R. Sustainability and Effectiveness of Chinese Outline for National Tourism and Leisure. *Sustainability* **2020**, *12*, 1161. [CrossRef]
50. Henzler, K.; Maier, S.D.; Jäger, M.; Horn, R. SDG-Based Sustainability Assessment Methodology for Innovations in the Field of Urban Surfaces. *Sustainability* **2020**, *12*, 4466. [CrossRef]
51. De Lotto, R.; Cattaneo, T.; Giorgi, E.; Venco, E. Coherences and Differences among EU, US and PRC. Approaches for Rural Urban Development: Interscalar and Interdisciplinary Analysis. *Sustainability* **2017**, *9*, 537. [CrossRef]

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Research on Population Development in Ethnic Minority Areas in the Context of China's Population Strategy Adjustment

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Abstract: Against the background of China's relaxation of family planning standards, this thesis analyzed the demographic trends in ethnic minority areas and their impacts on regional development under China's adjustment of its population strategy. By setting up different fertility scenarios, the population forecasting software (PADIS-INT) was applied to forecast the population scale and structure of the Hotan region. This thesis analyzed the impacts of population growth on regional sustainable development from the perspectives of employment, economic development, and resource carrying capacity to provide references for the formulation and implementation of population and economic development policies in minority areas, to alleviate the contradiction between the human and environment. The results showed that the Hotan region would maintain a relatively fast population growth rate for a long period; by 2050, its population would skew younger when compared to China's general statistics. However, due to the lagging economic development and the constraints to resources and the environment, unemployment would become the most severe problem hampering regional development. While developing its local economy, the Hotan region needs to better promote the interregional migration of the labor force.

Keywords: population development; labor force; employment; resource environment; ethnic areas

1. Introduction

In the context of global change, with the increase in the size of the population and its material and cultural needs, the intensity of human activities and their impact on the society, economy, and ecosystems have increased, and the internal conflicts in the human-environment relationship have become increasingly prominent [1–3]. The correlation between population and resources and environment is a central issue for regional sustainable development [4–6]. Humankind has long recognized that the Earth has limited space and resources. Humans have also realized the importance of living in harmony with nature, making great efforts to learn about their surrounding resources and environment [7]. The survival and development of human beings need to obtain sufficient means of production from the resource and environment system. However, under certain technological conditions, the demand of human beings exceeds the supply of the resource and environment system, which will lead to the deterioration of the environmental system and endanger the survival and development of human beings. Maintaining the population within the carrying capacity becomes the scale to measure the state of regional sustainable development. The Malthusian theory of population [8], Schultz's human capital theory [9], and the demographic dividend theory of Bloom et al. are all concerned with the effects of population growth externally [10]. The Limits

to Growth, published in 1972 by the Club of Rome, first defined the resource and environmental carrying capacity: Rapid industrialization, soaring population growth, food privatization, depletion of non-renewable resources, and degradation of the ecosystem. At some point, global growth will hit its limit due to food shortages and ecological devastation. That limit is the carrying capacity [11]. As its population continues to grow and socioeconomic development accelerates, problems such as resource shortages and environmental pollution have become increasingly important constraints to sustainable development in some parts of China. China has launched a series of scientific and technological projects targeting the north-west and the north-east regions to study the supporting capability and carrying capacity of resources and environment for each region's society and economy [12–18]. Studies have also been conducted on the supporting capabilities and protection levels of the resources and environment for each region's population and economy, pointing out that the increased vulnerability of the environmental system caused by the increase in human activities has become the main obstacle to the sustainable development of the regional ecological environment and social economy, and proposing measures to implement ecological migration, developing carbon sink industry, and protecting ecological water. The goal is to provide a scientific basis for the realization of regional resources and environmental security, as well as the sustainable development of the population's socioeconomic conditions [19–24].

To maintain the balance between population and resource environment, China has a long history of prioritizing population control. Since the implementation of family planning policies, 400 million fewer people have been born in China. In the early-1990s, the total fertility rate declined to a level far less than the replacement and has continued to decline, resulting in a fertility rate of 1.5 [25,26]. This has effectively alleviated the pressure that the population imposes on the environment and resources; however, the long-term low fertility rate has led to an ageing problem. Even after the Chinese government relaxed birth restrictions, the total fertility rate (TFR) continued to show a downward trend. An excessively low fertility rate can have a negative impact on socioeconomic development. As China's socioeconomic development enters a new era, China has shifted its population strategy from merely controlling the number to addressing specific issues (including population scale, structure, and quality) in a coordinated manner. The population strategy has also been adjusted from addressing internal problems of the population system to rational interactions with the external environment [27]. However, situations in ethnic minority areas are different from those in China as a whole. Due to preferential policies for ethnic minorities, family planning is already relatively loose in ethnic areas with relatively rapid population growth. Moreover, since most of China's ethnic minority regions are located in impoverished places (such as the frontier and drought-stricken areas) where economic development lags and productivity levels are low, increasing the labor force has been the main way out of poverty. Inhabitants in ethnic minority areas generally share a strong will to have children which has resulted in a population growth rate much higher than the national average. However, when the total population exceeds the carrying capacity of the region's resources and environment, it starts to cause unemployment and environmental crises. The population problem has become a critical constraint for the sustainable development of China's ethnic areas and the realization of poverty alleviation. However, there are few studies on the impact of the adjustment of family planning on population development in ethnic minority areas. On the southern edge of the Taklamakan Desert, Hotan in Xinjiang features a fragile ecological environment; it is a minority area located on the border and a contiguous area of extreme poverty. It is a typical "frontier, minority and impoverished" region in China. This case study used the example of the ethnic minority area of Hotan. The hypothesis was the abolishment of the family planning policy. By setting up different fertility scenarios, the PADIS-INT was applied to forecast the population scale and structure in Hotan in 2050. In the context of China's strategic shift in population development, the study analyzed the demographic trends in ethnic minority areas and the impact of such trends on each region's social economy, resources, and environment. The purpose was to supply reference material for the formulation and implementation of population and economic policies in minority areas.

2. Adjustment of China's Population Policies and the Current Situation of Population Development in Hotan

Statistics released by the National Bureau of Statistics from the fifth population census in 2000, the sixth population census in 2010, and the sample survey data of the 1% population in 2015 indicated that the total fertility rate in China had fallen below 1.5 and kept declining. This suggested that China may have been caught in a "low-fertility trap" (a total fertility rate below 1.5) which would lead to labor shortages, fewer children, ageing, and other social problems that would be detrimental to China's long-term development. In 2016, the Chinese government released the "Two-Child" policy with the intention of encouraging childbearing. However, according to statistics released by the National Bureau of Statistics in early 2018, China had 630,000 fewer births in 2017 than in 2016 and the birth rate dropped by 0.52% to 12.43% (a figure even lower than Japan's birth rate). The natural population growth rate had fallen to 5.32%, an alarmingly low level. This indicated that the "Two-Child" policy failed to stem the downward trend in the fertility rate. In order to reach a total fertility rate of approximately 1.8 as planned, it will be necessary to abolish all birth restrictions.

Due to China's vast territory and numerous ethnic groups, attitudes towards fertility vary greatly among different regions. In terms of ethnic groups, the Uighurs accounted for 96.92% of the total population of Hotan in 2017. The family planning policy in ethnic minority areas is relatively loose in consideration of their traditions. Urban ethnic minorities are allowed to have two children, while rural ethnic minorities are allowed to have three, both much higher than the number allowed for the Han ethnicity. Influenced by traditional values and religions, however, the local people have a stronger desire to have children. Results of the field research show that 51% of the respondents want to have more than three children. This explains the frequent violation of family-planning directives and the consistently high fertility rate in this area. According to the yearbook of demography of the Xinjiang Uyghur Autonomous Region, from 2000 to 2017 the average birth rate in Hotan was 21.94%, far higher than the figure of 16.01% for the Autonomous Region and 12.4% for the entire country during the same period. Hotan's total population amounted to 2,522,800 in 2017. With a population density of 300.66 people per square kilometer, the population carrying capacity of the oasis stood at a very high level. However, due to the lagging economy, the secondary and tertiary industries were less capable of attracting labor—A large number stayed in rural areas. However, the oasis contained limited land resources. Since the 1990s, the growing rural labor force had no fields on which to work. In addition, it is difficult for the workforce to migrate across regions due to language barriers, differences in religion and life practices, and lack of professional skills. The joint effect of high fertility rates, low labor mobility, and lagging development has resulted in "Population barrier lake" in Hotan, which means the growth of the labor force is considerably faster than the growth of employment. The work report of the Hotan government showed that over 600,000 workers (which made up 40% of the local workforce) in Hotan had no jobs and no fields. Most of these people are young adults born in the 1980s and 1990s; they impose a great negative impact on the stability of society if they idle around. To provide arable land resources to the growing rural labor force, the area of arable land in Hotan increased from 2,574,000 mu in 2010 to 2,824,400 mu in 2017. The expansion of arable land put great pressure on regional resources. The Hotan region has exceeded the target maximum of total water consumption set by the central government. According to the 2010 Hotan census, the population aged under 45 accounted for 80.72% of the total population, with a median age of 25.04. Women of reproductive age (between 15 and 49) made up 29.24% of the total population, and women in their most fertile age (between 20 and 29) made up 11.05%. The region of Hotan has an expansive population pyramid which indicates that the growth rate will remain high for a long period. Excessive population growth and the resulting pressure on employment, resources, and the environment have become core constraints to the sustainable development of the Hotan region.

3. Materials and Methods

3.1. Data Sources

The data needed for the study are mainly from government data and field survey. Government data include Statistics released by the Xinjiang Bureau of Statistics from the sixth population census in 2010, Statistics from the 2010 Census of Hotan Prefecture, Statistical Yearbook of Hotan Prefecture from 2011 to 2018, and sample survey data of the 1% population in 2015. Survey data are the questionnaire survey conducted by the research team on the fertility intention and migration intention of the population in the Hotan region in 2016. The total number of questionnaires is 1036, mainly analyzing the local residents' fertility intention and migration intention.

3.2. Parameter Setting

PADIS-INT was applied to make projections on the population scale and age structure of the Hotan region in 2050. The software requires population projection parameters that include total fertility rate (TFR), life expectancy, gender ratio for new-borns, fertility patterns, and net inflow [28].

The total fertility rate is the key indicator for the projections; however, relevant statistics are available only from the decennial census. To discover the total fertility rate in Hotan from 2010 to 2017, different schemes of total fertility were set up with 2010 (data of 2010 The Sixth Population Census of Xinjiang Uygur Autonomous Region) as the starting year and 2017 (with the population data released in the 2017 Statistical bulletin on national economy and social development of the Hotan region) as the target year. The TFR was set to low and high based on fertility data from 2010 The Sixth Population Census of Xinjiang Uygur Autonomous Region and that of neighboring regions. Based on the calculation, the total fertility rate in Hotan during 2010–2017 was determined, based on which the demographic trend in Hotan in 2050 was projected.

The Low TFR: It was set at 1.8, the TFR from 2010 The Sixth Population Census of Xinjiang Uygur Autonomous Region.

The High TFR: Taking Pakistan (which was at a similar level of religious practice and economic development to the Hotan region) as a reference, the initial TFR in Hotan was set at 3.3, based on the 2011 total fertility rate data for Pakistan published by the United Nations Population Division.

Average life expectancy: Due to the lack of gender-specific life expectancy data for the Hotan region in 2010, the 2010 life expectancy in Xinjiang (70.30 for males and 74.86 for females) was used instead. The total fertility rate determined was used as a benchmark to calculate the annual gender-specific life expectancy for the Hotan region from 2010 to 2050 using the United Nations Life Expectancy calculation.

Gender Ratio of Newborns: According to The Hotan Region Statistical Yearbook, the mean gender ratio of the population of the region from 2001 to 2017 was 104.28 and the figure each year was relatively stable. Therefore, it was assumed that the gender ratio for newborns in the Hotan region was 104.28 during the period to be estimated.

Fertility patterns: There was a lack of data on age-specific fertility rates for women of reproductive age (15–49) in the Hotan region. The only available data were grouped by five years and were very close to those of the whole Xinjiang region (for rural areas). Therefore, the age-specific fertility rate in the Xinjiang region was taken to substitute the age-specific fertility rate in the Hotan region.

Migration: There was a lack of gender-specific demographic data on migration in the Hotan region. Since the changes in the total population of a region are caused by the combined effect of natural and mechanical changes, the number of mechanical changes can be calculated from the annual changes in the total population and the number of natural changes in the Hotan region and the number of mechanical changes was taken as the number of net migration. In order to improve the accuracy, the total population and the number of natural increases of the population from 2000 to 2017 were collected to calculate the number of migrations per year, which was positive at 13,307 as the average annual net migrant population in Hotan. Assuming a one-to-one gender ratio of the population

moving in each year and the number of people moving in during the period to be estimated remains unchanged, the number of migrant populations for each gender in the Hotan region during the period was 6653.

Migration mode: The ratio of the migrant population by age and by gender to the total migrant population was calculated according to the 2010 Hotan census.

3.3. Total Fertility Rate and Setting Fertility Scenarios

3.3.1. Determination of the Total Fertility Rate

The total fertility rate was set at 1.8 and 3.3, respectively with 2017 set as the target year. In the results given by PADIS-INT, the 2017 population estimated is 2,512,600 when the TFR is high. This is very close to the actual figure of 2,522,800 in 2017, with an error of only 0.4% (Table 1). The error between the low TFR and the real data is large, the error rate is as high as 8.82%, so it can be determined that 3.3 is the current total fertility rate in the Hotan area.

Table 1. Comparison of population estimated with the high and low total fertility rate (TFR) and the actual population in 2017.

	Low TFR	**High TFR**	**Actual Population**
Population in 2017 (ten thousand people)	230.02	251.26	252.28

3.3.2. Setting Fertility Scenarios

Based on the data from the Sixth Population Census in Hotan, the total fertility rate was set at 3.3 as estimated in 2010–2017. Considering that the Chinese government may abolish the family planning policy in the near future, the total fertility rates in Hotan were set at three levels: Low, medium, and high. Other parameter settings remained unchanged, referring to the fertility rate changes in some Muslim countries released by the United Nations Population Division.

The Low TFR: As can be seen from the 2017 population, the total fertility rate in Hotan was comparable to that in Pakistan, where there is no family planning. It showed that the current family planning policy is of little constraint to local people, whose fertility intentions have been fully expressed. This indicated that even if the family planning policy was abolished, it would not bring about an obvious increase in local fertility intentions; this has already been proved by practices of China's hinterland provinces and those of Iran. Due to the socioeconomic development and the growing influence of modern values, the local fertility rate will continue to decline, assuming a gradual decline from the current 3.3 to 1.8 in 2050.

The Medium TFR: According to research in Hotan, 51% of the respondents think that the current three-child policy does meet their expectations; they want to have more children. Among those respondents, 66.9% wanted to have four children. In the meantime, 68.8% of the respondents expressed an intention to have fewer children due to the pressure of raising them and the harsh employment market. Thus, in the medium TFR scenario, it was assumed that the termination of family planning would not lead to a significant increase in fertility intentions: The total fertility rate in Hotan would rise slightly from the current 3.3 to 3.5 and then begin to decline until reaching 2.1 in 2050.

The High TFR: This assumes that the termination of family planning will greatly stimulate the local repressed intention to have more children. According to the survey, among the respondents who want to have more children, most of them choose to have four. Thus, this scenario assumes that the termination of family planning will lead to an increase in the local total fertility rate from 3.3 to 4.0 and thereafter gradually decrease to 2.1 in 2050 (Table 2).

Table 2. The low, medium, and high TFRs.

Scenario	2011–2019	2020–2029	2030–2039	2040–2050
Low	3.3	3.0	2.5	1.8
Middle	3.3	3.5	2.8	2.1
High	3.3	4	3	2.1

4. Results and Analysis

4.1. Total Population

The PADIS-INT was applied to give projections with low, medium, and high TFR scenarios. The results of all scenarios showed that in the longer term, the population in Hotan would keep a steady growth. In the Low TFR Scenario, the total population of Hotan will grow from 2,010,000 in 2010 to 4,430,700 in 2050, with an average annual growth rate of 1.99%. In the Medium TFR Scenario, the total population of Hotan will reach 4,760,900, with an average growth rate of 2.17%. In the High TFR Scenario, the total population of Hotan will reach 4,958,600 in 2050 (Table 3), with an average annual growth rate of 2.28%.

Table 3. The total population projection in the Hotan Region (10,000 people).

Year	Low TFR Scenario	Medium TFR Scenario	High TFR Scenario
2020	272.17	273.22	274.27
2030	333.36	344.24	354.91
2040	392.11	411.02	426.58
2050	443.07	476.09	495.86

4.2. The Population Structure

4.2.1. The Age Structure of Population and the Trend

The conclusions can be drawn from the population age pyramid in 2050 that regardless of scenario, the population age structure of Hotan will appear pyramidal (Figure 1). Moreover, the population under age 40 takes up a large proportion: 59.95%, 62.73%, and 64.21% of the total population in terms of the low, medium, and high TFR scenarios, respectively—with the median age being 33.18, 31.05, and 29.81. Compared to the median age of 37 among Chinese people in 2015 and 49.6 in 2050, the age structure of the population in the Hotan region appears extremely young (Figure 2).

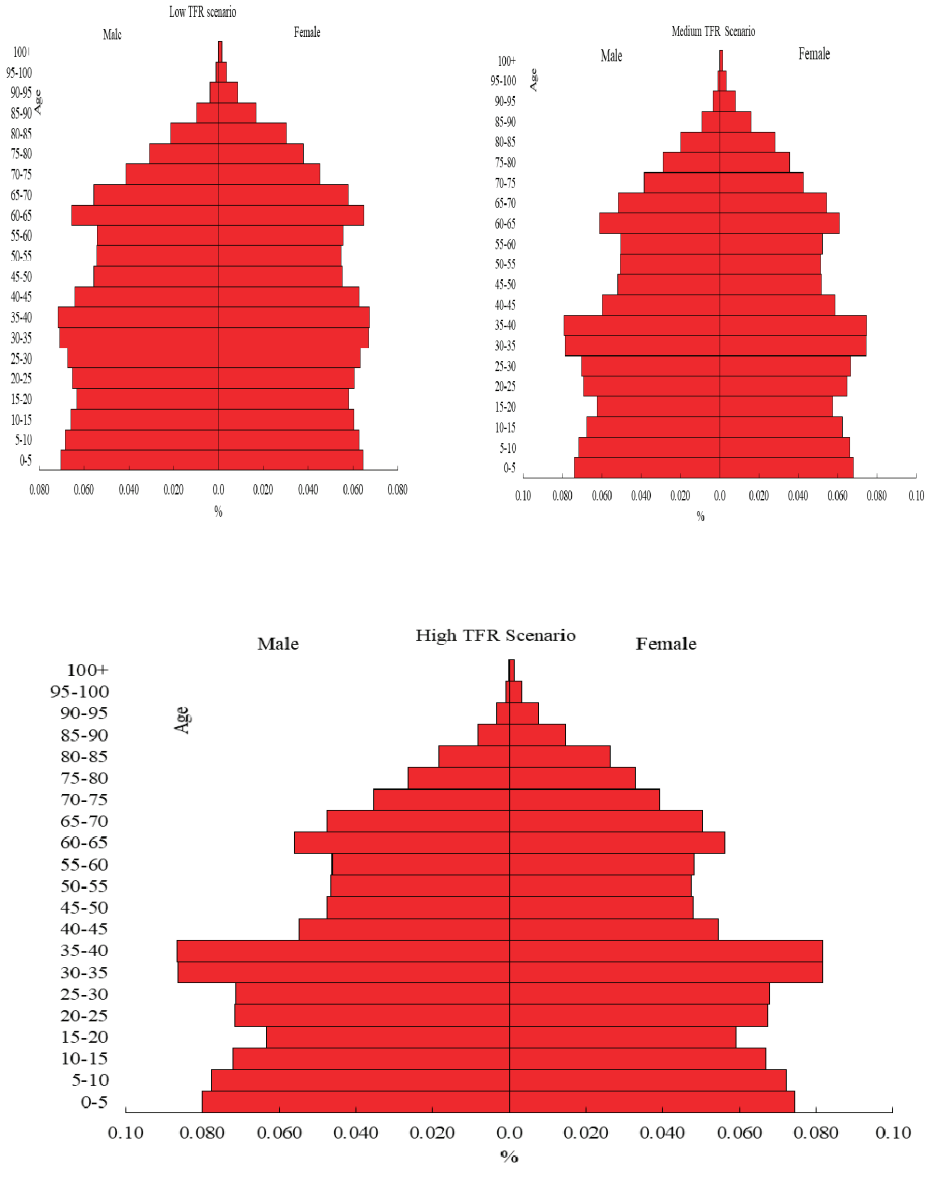


Figure 1. The population age pyramids of the Hotan region in 2050.

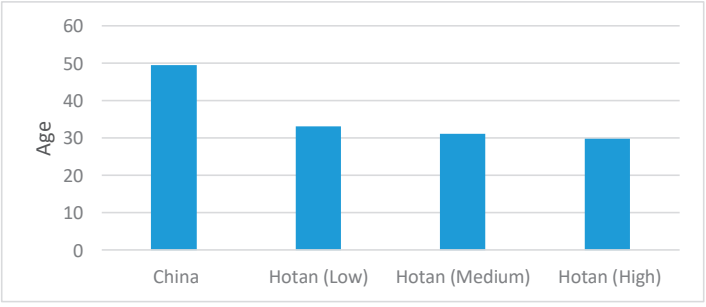


Figure 2. Comparison of the medium ages in 2050.

4.2.2. Changes in the Labor Force

The increasingly youthful age structure of the population produces a large workforce. Internationally, the working age is generally defined as those aged 15–64. According to the projections, the labor force in the Hotan region for the low, medium, and high TFR scenarios will reach 2,874,600, 3,017,700, and 3,147,000, respectively by 2050. Compared to the figure of 1,398,300 in 2010, the labor force in either scenario will more than double by 2050 (Figure 3), taking up between 63% and 64% of the total population. More than 600,000 of the labor force are now unemployed with no arable land, as local natural resources are limited. If secondary and tertiary industries are not maintained at a high rate of growth or the interregional flow of the workforce is not promoted, the number of unemployed people will double, posing enormous pressure to social stability.

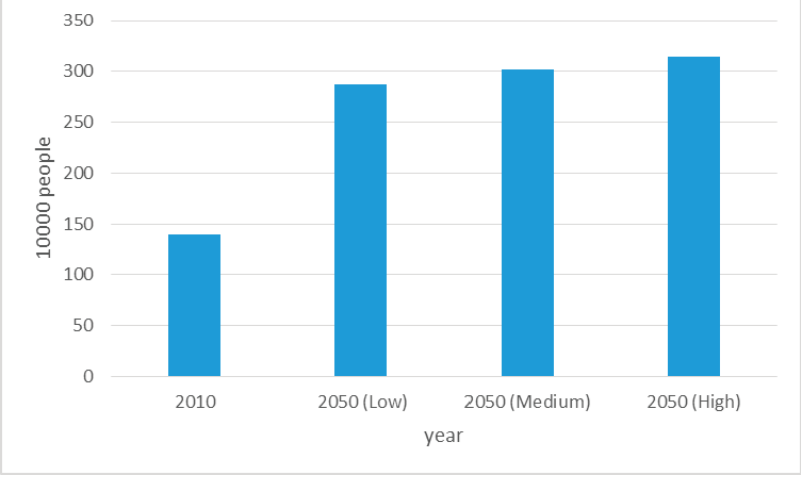


Figure 3. Comparison of the number of labor force in Hotan.

4.2.3. The Number of Women of Reproductive Age and Trends

The number of women of reproductive age affects the future demographic trend. The number of women of reproductive age in Hotan will increase from 603,000 in 2010 to between 1,084,900 and 1,218,800 in 2050. Among them, the number of women in the peak reproductive age (age 20–29) will increase from 222,300 to between 329,800 and 425,100 (Figure 4). The women of childbearing age in all three scenarios accounted for around 24% of the total population, with a decrease of 5% (from 29.94%) in 2010. Meanwhile, the proportion of women of childbearing age ranged between 7.44% and 8.57%,

with a decrease of 3–4% compared to 2010. Despite this decline, the absolute number of women of childbearing age will nearly double in the next three decades.

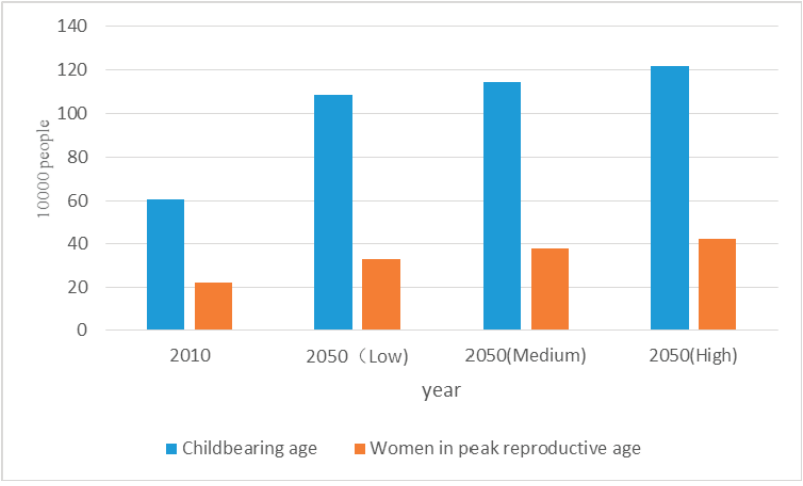


Figure 4. Change in the number of women of reproductive age by 2050.

4.2.4. Social Dependency Ratio and Trends

Following international standards, the child dependency ratio is defined as the number of the population aged 0–14 to the population aged 15–64. The old-age dependency ratio is defined as the number of the population aged 65 and above to the population aged 15–64 years. The total dependency ratio is the sum of the child dependency ratio and the old-age dependency ratio. According to the projection results, the population aged 0–14 in Hotan will increase from 528,300 in 2010 to between 930,500 and 1,185,900 in 2050 and the child dependency ratio will increase from 37.78% in 2010 to between 54.13% and 57.77% in 2050. The number of people aged over 65 is influenced by high fertility rates in the early period and will rise sharply from 87,700 in 2010 to 625,600 in 2050, an increase of 7.13. The old-age dependency ratio will rise from 6.27% to 19.88–21.76%. The elderly-youth ratio, influenced by the increase in the elderly population, will increase from 16.6% in 2010 to between 52.75% and 67.23% in 2050. The social dependency ratio increased from 44.05% in 2010 to 74.01–79.53% in 2050, promoted by the rise of the old-age dependency ratio.

In all scenarios, comparing the population structure of Hotan in 2050 based on the United Nations classification criteria of population structure types (Table 4), the Hotan region has already entered into an ageing society in 2050. However, the median age of the Hotan region in the three scenarios is 33.18, 31.05, and 29.81, respectively. Comparing those results with the United Nations Population Division's estimates on the median ages of various countries in 2050, the median age of the Hotan region in 2050 is not only much lower than that of China (49.6) but also much lower than that of Muslim countries such as Iran and Saudi Arabia—and on par with that of Afghanistan [29] (Table 5). Therefore, due to the influence of rapid population growth, the Hotan region will face pressure from both a tough employment situation and the heavy burden of social support in the near future. However, the proportion of the workforce in the total population will stay between 63% and 64%, with a median age of around 30. Although the Hotan region will have already entered into an ageing society by the current criteria, its population structure is still relatively youthful compared to the population structures of other countries in 2050. Although the Hotan burden of social support will rise in the near future, the principal contradiction in society will still be focused around the employment problem of a large number of workers brought about by the population growth.

Table 4. Categorization criteria of the population structure.

	Old-Age Ratio	Child Ratio	Elderly-Youth Ratio	MEDIAN AGE
Expansive	Below 4%	Below 40%	Below 15%	Below 20
Constructive	4–7%	30–40%	15–30%	20–30
Ageing	Over 7%	Below 30%	over 30%	over 30

Table 5. Median age in 2050.

China	China (Hotan)			Saudi	Indonesia	Pakistan	Afghanistan	Iran
	Low Scenario	Medium Scenario	High Scenario					
49.6	29.81	31.05	33.18	38.2	36.5	30.9	29.8	44.7

5. Discussion

The complete lifting of birth restrictions is to take place in the near future. Due to the expansive population structure of Hotan, its population growth area will see a rapid increase after the abolition of the family planning policy. Located on the southern edge of the Taklamakan Desert, the Hotan region is an arid and ecologically fragile area. In order to protect the environment, the Chinese government has set a limit on the total amount of water used in each region, known as "the red line for water resources". However, the local government has continued to increase the development of land and water resources to meet the needs of the growing workforce. The area of arable land increased from 2,574,000 mu in 2010 to 2,824,400 mu in 2017. However, due to the rapid population growth, the arable land per capita was only 1.12 mu. Moreover, the expansion of arable land has already put tremendous pressure on regional resources and the environment. The exploitation rate of water resources in Hotan was as high as 79.86%, 98% of which was taken up by agricultural use. Internationally, it is generally believed that the development and utilization of water resources should not exceed 40% of its water resources. The threshold of water resources development and utilization of China's seven major rivers is 31% to 45%, and for relatively fragile ecological environment in the northwest arid region, the proportion of resource development utilization rate should not exceed 50% [30], and the utilization rate of Hotan water resources development is much higher than the reasonable level. The total water consumption in Hotan in 2015 had already exceeded the national water consumption control target by 2030 by nearly 700 million cubic meters, which indicated that the expansion of arable land could no longer continue.

Since there is no room for expanding arable land, the main solution to the employment problem is to transfer the workforce from the primary industry to secondary and tertiary industries. In 2017, the ratio of the primary, secondary, and tertiary industries in the Hotan region was 22.28:17.9:59.8. In terms of the output value, the secondary industry's output was lower than that of the primary industry. The urbanization rate in 2017 was merely 19.77% and the GDP per capita was RMB 10,400. Agriculture was the pillar of industrial development, absorbing up to 68.2% of the labor force. The Hotan region was still in the stage of transformation from an agricultural society to early industrialization. The Hotan region has been developing textiles and other labor-intensive industries in recent years to boost employment capacity. There was an increase in the employment elasticity coefficient, which reached 1.08 in 2017. Assuming that the employment elasticity can be maintained over the long term by excluding the declining effects brought about by technology and capital substitution, if the Hotan region seeks full employment its economic growth rate should be at least 9.55% for the next three decades (to meet the amount of newly increased workforce estimated in whichever scenario of population projection). Compared to China's development since the reform and opening up, such a growth rate may not seem too difficult in the early stages; however, as the total volume of the economy increases, the growth rate will inevitably be slow. Considering that the industrial base of the Hotan region and its geographical location are far from China's major consumer markets, it is basically impossible to maintain such high growth for the next three decades. If economic

growth does not achieve the expected speed, the number of unemployed and landless workforce could surpass one million.

It is difficult to rely entirely on the Hotan region to solve the employment problem for the newly added workforce. The ultimate way to solve the problem is by cross-regional employment, which is to encourage the outflow of the local labor force to well-developed areas. However, Hotan is an ethnic minority region. Due to many restrictions including the language barrier, great differences in living habits and religious customs, strong emotional attachment to the hometown, and lack of professional skills, Hotan does not see a great deal of mobility among its population. Local residents are generally unwilling to migrate. Even for those who choose to work outside their hometown, the Hotan region continues to be their home. Among the more than 1000 residents surveyed, 91.32% were unwilling to move outside Hotan for employment. The relatively closed geographic and social environment in Hotan makes it difficult to achieve a large-scale population mobility. In order to promote the population mobility while respecting unique cultural customs, it would be appropriate to establish Uyghur gathering areas in other cities (similar to other countries' designations of "Chinatowns"). By creating a homelike living environment, the Uyghur people's worries can be alleviated and they may be more comfortable seeking employment in other provinces.

The development of education is the fundamental strategy to solve the contradiction between population and resource environment in Hotan. According to statistics from the Sixth Population Census in Hotan, 89.06% of the workforce has only a junior high school education or less. The National Family Planning Commission's survey on China's fertility status shows that when women have been educated for more than 7 years, the average number of children born per person is 2.2 fewer than those without education. Low academic qualifications not only increase the fertility rate, but also make it difficult for the huge population to turn into a "demographic dividend", but it has become a heavy social burden. Raising educational standards to prepare a more qualified workforce is a premise for changing the region's lagging development. The Hotan region should further invest in education to build a system that comprises compulsory, vocational, adult, and higher education. By improving the professional skills of the workforce, it will lay a foundation for the outward mobility of the workforce while training talents for local socioeconomic development.

6. Conclusions

Against the background of China's relaxation of family planning standards, this thesis analyzed the demographic trends in ethnic minority areas and their impacts on regional development under China's adjustment of its population strategy. The results showed that the Hotan region would maintain a relatively fast population growth rate for a long period; by 2050, its population would skew younger when compared to China's general statistics. However, due to the lagging economic development and the constraints to resources and the environment, the "Population barrier lake" in Hotan may be more severe [4]. Due to the lack of data, this paper is not in-depth enough to analyze the impact of population flow and population internal structure changes on the regional resources and the environment. In the future, it is necessary to strengthen data collection, establish long-term population structure data, and systematically analyze the relationship between population and resources and environment.

Author Contributions: J.H. conceived and designed this study; X.Z. retrieved and analyzed the data; Z.Z. contributed analysis software; J.H. wrote the paper; Y.C. revised the paper. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Han, X.; Wang, P.; Wang, J.; Qiao, M.; Zhao, X. Evaluation of human-environment system vulnerability for sustainable development in the Liupan mountainous region of Ningxia, China. *Enviorn. Dev.* **2020**, *34*, 1–12. [CrossRef]
2. Zhang, Q.; Song, C.; Chen, X. Effects of China's payment for ecosystem services programs on cropland abandonment: A case study in Tiantangzhai Township, Anhui, China. *Land Use Policy* **2018**, *73*, 239–248. [CrossRef]
3. Zhang, Q.; Bilsborrow, R.E.; Song, C.; Tao, S.; Huang, Q. Determinants of out-migration in rural China: Effects of payments for ecosystem services. *Popul. Enviorn.* **2018**, *40*, 182–203. [CrossRef]
4. Junjie, L.; Lina, L. The Research on the Trend of Carrying Capacity of Resources and Environment Based on Population Predictions in Ethnic Regions. *Ethno Natl. Stud.* **2014**, *5*, 28–38.
5. Hoekstra, A.Y.; Wiedmann, T.O. Humanity's unsustainable environmental footprint. *Science* **2014**, *344*, 1114–1117. [CrossRef]
6. Mannschatz, T.; Wolf, T.; Huelsmann, S. Nexus Tools Platform: Web-based comparison of modelling tools for analysis of water-soil-waste nexus. *Environ. Model. Softw.* **2016**, *76*, 137–153. [CrossRef]
7. Liang, W.; Hui, L. Evaluation of regional resources and environmental carrying capacity based on PS-DR-DP theoretical model. *J. Geogr. Sci.* **2019**, *29*, 363–376.
8. Malthus, T.; Wei, D. *The Principles of Population*; Dunhuang Literary Publishing House: Dunhuang, China, 2007.
9. Schultz, T.W.; Bin, J. *Investment in Human Capital: The Role of Education and Research*; The Commercial Press: BeiJing, China, 1990.
10. Bloom, D.; Canning, D.; Sevilla, J. *Economic Growth and Demographic Transition*; The National Bureau of Economic Research: Cambridge, MA, USA, 2002.
11. Medus, D.; Baoheng, L. *The Limits of Growth: A Report for the Club of Romes Project on the Predicament of Mankind*; Jilin People's Press: Changchun, China, 1997.
12. Water Resources in Northwest Region Task Group of Chinese Academy of Engineering. *Strategic Study on Allocation of Water Resources, Conservation and Upgrading of Eco-Environment and Sustainable Development in North-West China*; Engineering Science: Oxford, UK, 2003.
13. Hao, W.; Jian, C.M.; Yong, Q.D. *Research of Water Resource Rational Allocation and Carrying Capacity in Northwest China*; Yellow River Water Conservancy Press: Zhengzhou, China, 2003.
14. Zhi-Ming, F.; Yan-Zhao, Y.; Zhen, Y. Research on the Water Resources Restriction on Population Distribution in China. *J. Nat. Resour.* **2014**, *29*, 1637–1648.
15. Resources, W. CAE, Strategic Concern to Land and Water Resources Allocation, Ecology and Environment Protection and Sustainable Development of Northeast China. *Eng. Sci.* **2006**, *8*, 1–24.
16. Cheng, J.; Zhou, K.; Chen, D.; Fan, J. Evaluation and analysis of provincial differences in resources and environment carrying capacity in China. *Chin. Geogr. Sci.* **2016**, *4*, 539–549. [CrossRef]
17. Yin, Z.; Qinyuan, Y.; Jie, M. An analysis of coupling between the bearing capacity of the ecological enviroment and the quality of new urbanization in Chongqing. *Acta Geogr. Sin.* **2016**, *71*, 817–828.
18. Zhang, S.H.; Ruan, D.B. Evaluation of resource and environment carrying capacity from the perspective of resource cross-regional mobility: A dynamic evaluation framework and practice. *J. Nat. Resour.* **2020**, *8*, 1–11.
19. Gong, L.; Jin, C. Fuzzy Comprehensive Evaluation for Carrying Capacity of Regional Water Resources. *Water Resour. Manag.* **2009**, *23*, 2505–2513. [CrossRef]
20. Qian, L.X.; Wang, H.R.; Jiang, G.R.; Yu, S. Model for Risk Analysis between Supply and Demand of Water Resources Based on Logistic Regression and NFCA and Its Application. *J. Nat. Resour.* **2011**, *12*, 43–53.
21. Song, X.; Kong, F.-Z.; Zhan, C.-S. Assessment of Water Resources Carrying Capacity in Tianjin City of China. *Water Resour. Manag.* **2010**, *25*, 857–873. [CrossRef]
22. Chang, T.; Yang, D.; Huo, J.; Xia, F.; Zhang, Z. Evaluation of Oasis Sustainability Based on Emergy and Decomposition Analysis. *Sustainability* **2018**, *10*, 1856. [CrossRef]
23. Lu, H.W.; Huang, G.H.; He, L. Development of an interval-valued fuzzy linear-programming method based on infinite α-cuts for water resources management. *Environ. Model. Softw.* **2010**, *25*, 354–361. [CrossRef]
24. Liu, Y. Sustainable Development in Urban Areas: Contributions from Generalized Trade. *Sustain. Cities Soc.* **2020**, *61*, 1–7. [CrossRef]

25. Luo, D.; Yan, X.; Xu, R.; Zhang, J.; Shi, X.; Ma, J.; Song, Y.; Patton, G.C.; Sawyer, S.M. Chinese trends in adolescent marriage and fertility between 1990 and 2015: A systematic synthesis of national and subnational population data. *Lancet Glob. Health* **2020**, *8*, e954–e964. [CrossRef]
26. Murray, C.J.L.; Callender, C.S.K.H.; Kulikoff, X.R.; Srinivasan, V.; Abate, D.; Abate, K.H.; Abay, S.M.; Abbasi, N.; Abbastabar, H.; Abdela, J.; et al. Population and fertility by age and sex for 195 countries and territories, 1950–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **2018**, *392*, 1995–2051. [CrossRef]
27. Kun, C. *Study on the Economic Effect of Xinjiang Population Spatial Pattern*; Shihezi University: Shihezi, China, 2020.
28. Liu, H.; Jin, W. *Gansu Population Prediction Research Report*; Analysis Based on PADIS-INT; Gansu People's Publishing House: Lanzhou, China, 2014.
29. World Population Prospects: The 2015 Revision. Available online: https://population.un.org/wpp/Publications/Files/Key_Findings_WPP_2015.pdf (accessed on 10 November 2019).
30. Wang, X.Q.; Zhang, Y. The Allowable Exploitation Rate of Rivers Water Reso urces of the Seven Major Rivers in China. *J. Nat. Resour.* **2008**, *23*, 500–506.

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Research on Network Patterns and Influencing Factors of Population Flow and Migration in the Yangtze River Delta Urban Agglomeration, China

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Abstract: Through the construction of a population flow and migration relationship matrix, this paper analyzes population flow and migration in the Yangtze River Delta urban agglomeration during the Spring Festival travel rush and daily period. This paper also studies the urban network spatial structure characteristics and the influencing factors from the perspective of inter-provincial population flow and migration. The results show the following: (1) as a central city, Shanghai has a significant siphon effect, with Suzhou, Nanjing, Hangzhou, Ningbo, Wuxi and Changzhou accumulating 86.95% of the incoming population. The Shanghai–Jiangsu cross-border floating population is active and accounts for 40.83% of the total mobility scale in the same period. The population flow and migration network in the Yangtze River Delta urban agglomeration shows obvious hierarchical characteristics. The secondary network relationship during the Spring Festival travel rush is the main migration path, while the first-level network relationship in the daily period is the main flow path. (2) Three indicators, namely, the network density, mean centrality, and control force based on the population flow and migration, consistently show that the Yangtze River Delta urban agglomeration network presents a strong connection state with the formation of a local cluster structure, highlighting that the city tightness in terms of population flow and migration also has dual attributes, which refers to "the restriction of the geographic space effect" and "overcoming the friction of space". (3) Economic scale, political resources, industrial structure, and the historical basis are important factors influencing the formation of population flows and migration networks. Employment opportunities and labor wages are key guiding factors of the population migration direction, and spatial distance is a conditional factor influencing the formation of population flows and migration networks. The inter-provincial boundary, temporal distance, and transboundary frequency are the decisive factors for the formation of network patterns of population flow and migration.

Keywords: population flow; population migration; network structure; influencing factors; inter-provincial boundary; quadratic assignment procedure; Yangtze River Delta urban agglomeration

1. Introduction

An urban network is a kind of urban relationship generated in a relatively unconstrained space–time scale by flow factors such as production, service, information and traffic, etc. [1]. A multi-scale urban network and the consequent difference research methods are the advantages of an urban network in the study of urban systems [2]. Urban network studies based on the perspective of urban agglomeration have attracted a great deal of attention. At present, scholars have revealed the spatial structure characteristics of urban agglomerations from the perspectives of

structure compactness [3], stability [4], economic connection [5], factor analysis [6], the man–land relationship [7], and the multi-center network development mode [8]. Studies on the Yangtze River Delta, the urban agglomeration with the highest development maturity in China, paid more attention to regional cooperation, regional spatial coordination, and development path exploration [9,10]. As the integration of Yangtze River Delta has become a national strategy, theoretical and empirical studies on urban innovation [11], isomorphism [12], the metropolitan area [13], and spatial connection have increased [14,15]. However, integrative development is faced with the dual problems of constructing a regional network and eliminating the restriction of boundaries. On the one hand, creating networks is necessary for the integrated development of urban agglomerations. Under the background of flow space, various high-speed infrastructure and information networks make the connections between cities extend beyond the cognitive limits of the previous central place era and form a network relationship of sharing space and time between cities of multiple spatial scales and levels. Due to the regional division of labor and functional supplements, spatial flow, as the essential content of urban spatial connection, becomes a spatial vector with direction and intensity, and its change will lead to a change in the regional connection network, thus leading to the generation of a spatial difference [16]. As the network relationship between cities has been gradually strengthened, the urban flow gradually blurs administrative boundaries, which makes the relative position, relative correlation, and interaction of cities within the region present new characteristics [17]. On the other hand, the inter-provincial boundary is a realistic problem facing the integrated development of urban agglomerations. Since the beginning of the 21st century, boundary research has gradually emerged, mainly focusing on boundary trade [18,19], market segmentation [20], factor costs [21,22], capital differences [23,24], cross-border cooperation [25,26], structure estimation [27], and regional development and coordination [28–33], etc. However, because boundary discussions are mostly concentrated in the economic field, and the relative flow data between administrative regions are difficult to obtain, there are few studies based on the perspective of network relationships of factor mobility. With the continuous advancement of globalization and regional integration, the regional network, as a key part of the country and global network, makes the development of internal migration networks become the important component of the transnational network, as well as the basic unit of a transnational network's construction. So far, the perspectives of boundary research have constantly been diversified as follows [34]: economic geography regards economic activities as homogeneous elements and discusses the differentiation of the phenomenon of cross-regional economic development caused by administrative boundaries [35]. Urban geography regards urban attributes as homogeneous elements and discusses the differentiation phenomenon of cross-regional structure development caused by administrative boundaries [36–38]. Political geography regards political entities as homogeneous elements and discusses the differentiation of trans-regional cooperation mechanism and policy governance caused by administrative boundaries [39,40]. The problem is that the aforementioned research only focused on the phenomenon of regional differentiation caused by the objective existence of boundaries, including a lack of exploration in the construction paths and development mechanisms of the international network embedded in national boundaries with the background of globalization, as well as regional networks embedded in inter-provincial boundaries with the background of regional integration. As a unique product of administrative divisions in China, the objective existence of inter-provincial boundaries makes the regional differential size become a key factor influencing the formation and development of urban network relationships under the boundary theory system.

Population migration has been one of the largest and most far-reaching geographical processes since China's reform and opening up [41]. Social and economic development, reform of the household registration system, and construction of high-speed transportation facilities have promoted population flow and migration. On the one hand, the phenomenon of population flow in the daily stage, i.e., population flow as a process of the spatial reallocation of production factors, where its occurrence and development is an important driving force to promote social and economic development [42], is usually

accompanied by social and economic prices. In an urban network, the vertical, horizontal, formal, and informal links between various enterprises and organizations oriented by value creation constitute the basis for the existence of the population mobility network. On the other hand, the phenomenon of population migration during the Spring Festival travel rush is known as the most spectacular periodic population migration in human history. It has a completely different scale and characteristics as compared to daily population movement. In 2015, about 2.809 billion people migrated during the Spring Festival travel rush in China, among which the most significant part was the large-scale migration of the labor force from rural areas to cities (research on the characteristics and mechanisms of population migration based on these data can provide a good reference for similar research on characteristics of rural–urban migration in the process of industrialization in India, Mexico, Brazil, and other countries), which is also known as the "rite of passage" for rural young people [43]. In general, the regional economic development is not balanced, and the spatial disharmony between population distribution and economic activities leads to the differentiation of population and employment space. Cities in economically developed regions are more attractive than those in economically backward regions, so people tend to choose cities with more developed economies, more job opportunities and better infrastructure. Under the influence of traditional festival culture and customs, a large floating population flows from work cities to their home cities before the Spring Festival, forming the "return migration". After the Spring Festival, people return from their home cities to their work cities, forming the "rework migration". As a major social phenomenon unique to China, Spring Festival travel has become an important perspective to study the migration of floating populations [44–46].

Population mobility is a large-scale group behavior in space and time, and the estimated number of the floating population in China is very sensitive to the counting method used. Studies based on census data show that traditional destination surveys fail to account for more than a third of the floating population, where mainly young people and rural registered resident holders are included [47]. The arrival of the era of big data makes it possible to obtain human movement patterns based on massive spatiotemporal trajectories of individual granularity. The development of global positioning systems (GPS), location-based services (LBSs), and other technologies has provided technical support for the observation of spatial and temporal characteristics of large-scale population behaviors. These methods have been widely used in the study of human space trajectories and space interactions based on stream data [48]. The large number of mobile computing devices with positioning functions and the large amount of spatiotemporal labelled data with individual granularity (including mobile phone call data, bus card swiping records, social network check-in data, taxi tracking, bank card swiping records, etc.,) makes it possible to track individual movements for a long time with high precision and efficiency [49]. The study of individual or group behaviors based on big data, spatial cognitive rules, spatial behaviors and interaction patterns contained in activities is used to support cross-border flow decisions regarding social and economic factors, and this has become the frontier of geographic science research.

To sum up, this paper studies urban network structure characteristics and their influencing factors in the perspective of Spring Festival travel and daily population flow and migration. The research goals of this paper are the following: firstly, to carry out urban network construction and structural characteristics analysis based on the perspective of population flow and migration; secondly, to explore the influencing factors of the formation and development of urban networks based on a quadratic assignment procedure (QAP), improving and testing the influencing factor groups of the formation and development of the network structure. Existing research of network structure influence factors mainly include the economic scale level, political resources, facilities, service quality, living environment, and distance, etc. However, network construction is a process of breaking through and covering administrative boundaries. Therefore, how boundary variables affect the formation and development of a network is a topic worthy of discussion. Based on that, this paper adds three factors, namely time distance, and the administrative boundary, as necessary supplements to the existing element group because of China's special administrative divisions and transboundary frequency. At the same time, constructing a quantitative analysis system between the network matrix and the variable matrix, the

rationality and necessity of adding new elements is tested through the matrix correlation and regression analysis, as well as proving that the relationship between the urban network and inter-provincial boundaries is not a "false relationship". On the one hand, the research perfects the theoretical research system of an urban network and provides a scientific basis for the exploration of regional spatial networkization paths. On the other hand, it can provide a typical case analysis for research on the formation and development mechanisms of cross-boundary networks based on element flow under the background of globalization and regional integration.

2. Data and Methods

2.1. Research Area

The Yangtze River Delta urban agglomeration is one of the most developed regions in China's social economy and is also an important intersection of the Belt and Road Initiative and the Yangtze River Economic Belt. The economic hinterland of the Yangtze River Delta urban agglomeration is vast, with a modern river and seaport and airport groups. The expressway network is sound, the density of trunk lines of public and railway traffic is the highest in the country, and a three-dimensional and comprehensive traffic network has basically taken shape. In 2016, according to the "Yangtze River Delta Urban Agglomeration Development Plan", the Hefei metropolitan area in Anhui province was included into the Yangtze River Delta urban agglomeration, expanding its scope from "two provinces and one city" to the current "three provinces and one city". In terms of the geographical space, 26 cities, including Shanghai, Nanjing, Hangzhou, and Hefei (Figure 1), cover an area of 217,700 square kilometers. In 2019, the GDP of the Yangtze River Delta region was 19.74 trillion yuan, with a total population of 156 million, which accounts for 2.2 percent of the country's total land area, producing 19.92 percent of the country's production value and representing 11.11 percent of the population.

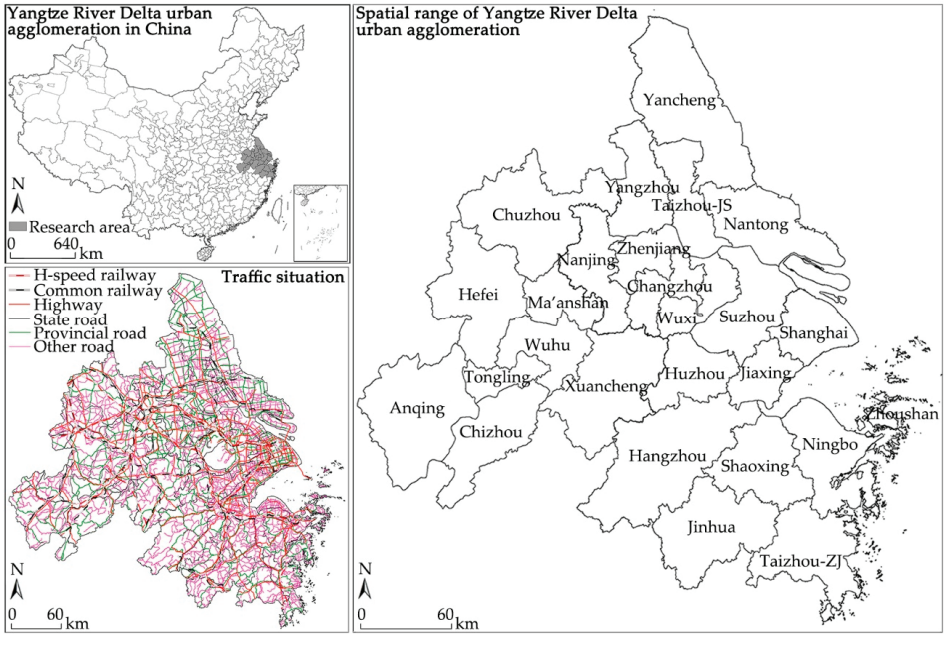


Figure 1. Research area scope map.

2.2. Data Sources

The migration data of the population involved in the study were sourced from the migration data of Baidu Maps. Based on LBS technology, Baidu migration maps the trajectory of population flow via the location information of mobile phone users and shapes the starting and ending nodes and relationship strengths generated in the process of population flow. The data of population migration consists of two parts: one is the Spring Festival transport data, which represents the characteristics of the net population migration in the Yangtze River Delta urban agglomeration; the second is the daily data, which is used to characterize the spatial network characteristics of population mobility in the Yangtze River Delta urban agglomeration. The study time was divided here into 40 days of Spring Festival travel from 7 February to 18 March in 2015 (the officially defined period of Spring Festival travel in China is generally 40 days, namely, 15 days before and 25 days after the Spring Festival) and 43 days of daily travel from 19 March to 30 April in 2015, which is not a major holiday period. During the 2015 Spring Festival travel rush, the Baidu migration platform identified 81.74 million instances of inter-provincial migration, involving 22,420 directional population migration paths. After processing, the scale of population migration was found to be 466,400. In the daily 43 days, Baidu migration identified 38.54 million people moving between provinces. Through the Spring Festival travel and daily Baidu migration data, the population flow and migration matrices among 26 cities in the Yangtze River Delta urban agglomeration were constructed, which serves as the basis for the analysis of the network structure characteristics of the Yangtze River Delta urban agglomeration. In addition, the index data related to the social and economic development of cities involved in the study were derived from the statistical yearbooks of the provinces (or cities) and statistical bulletins of the national economic and social development of cities.

2.3. Research Methods

2.3.1. Social Network Analysis

According to the analysis method of a social network, a society is a huge network composed of various relationships and each actor is a node in the network. By studying the network relationships, the relationship between individuals can be grasped so as to reveal the integration and hierarchies of the network. This paper uses the social network analysis method to quantitatively analyze the network structure characteristics of population migration in the Yangtze River Delta urban agglomeration from three aspects, namely, the network density, centrality, and control force.

Network density refers to the degree of the closeness of connections between nodes in a relational network, which is obtained by dividing the number of actual connections in the network by the number of theoretical connections. The calculation formula is the following:

$$D = \sum_{i=1}^{k} \sum_{j=1}^{k} d\left(n_i, n_j\right) / k(k-1) \quad (1)$$

where D is the network density, k is the number of nodes in the city, n_i and n_j are any two node cities, and d is the strength of the relationship between the two cities, which is represented by the population flow weight in this paper.

Centricity reflects the population of a region or urban agglomeration in terms of the resource capacity and it can reflect a city's ability to absorb foreign population inflows, with net ingoing values used to measure population during the Spring Festival. Based on the Spring Festival time schedule and overall observation of the data, this determined that the segmentation point of return and rework population migration is midnight on the 24 February. Based on the time arrangement and overall observation of the data, the starting and ending times for return migration were determined as 7–23 February before the festival, with the dominant direction of migration by the Yangtze River Delta urban agglomeration being internal to the external diffusion (diffusion, D). The rework migration after

the festival occurs from 24 February to 18 March, and the leading direction of population migration is aggregation from the outside to the inside of the Yangtze River Delta urban agglomeration (aggregation, A). The calculation formula of this is given as follows:

$$Centrality_i = \sum NI_{i_dayA} - \sum NI_{i_dayD} \quad (2)$$

In the formula, $Centrality_i$ represents centrality of a city. When $Centrality_i > 0$, this indicates that city i is the move-in place of population migration during the Spring Festival travel rush, while when $Centrality_i < 0$, city i is the move out place of population migration during the Spring Festival travel rush. NI_i is the flow scale of the urban population in city i and NI_{i_dayA} is the net flow scale of urban population in city i before the festival, while NI_{i_dayD} is the net flow scale of urban population in city i after the festival.

The control force is the total intensity of the inter-provincial population flow during daily life, which can reflect the active degree of the population flow in a city. It can be measured by the total flow scale. The calculation formula of this is given as follows:

$$Power_i = R_i^T + R_i \quad (3)$$

where R_i is the inter-provincial flow matrix of population and $R^T{}_i$ is the R_i -transpose matrix. According to the calculation demand, this paper constructs the matrix of population resettlement intensity of 26 cities in the Yangtze River Delta urban agglomeration, the whole country, and the urban agglomeration itself.

2.3.2. Quadratic Assignment Procedure (QAP)

The QAP can be used to study the relationship between relationships, namely, to study the correlation and regression between matrices. The QAP needs to construct the city attribute relationship matrix. If a certain attribute of city i and city j is the same, the encoding value at the intersection of i and j in the attribute relation matrix is 1, otherwise the encoding value is 0. Based on a directed, weighted asymmetric matrix during the Spring Festival, the daily time undirected, weighted symmetric matrix, and the city attribute matrix, matrix correlation analysis (QAP correlation) and matrix regression analysis (QAP regression) were performed. The former is used to test the correlation relationship between a population flow network matrix and city property matrix, such as the border area or transboundary frequency, and the latter is used to quantitatively identify the influence of the city property matrix on the population migration network matrix.

3. Analysis of Urban Network Pattern

3.1. External Connection of Population Resettlement

During the Spring Festival travel rush, the total net immigration population was 11.33 million people, accounting for 24.3% of the national total. Twelve cities, including Shanghai, Suzhou, and Hangzhou, saw a net migration of more than 10 million people, while 13 cities, including Zhoushan, Tongling, and Hefei, saw a larger emigration than the number of people moving in (Table 1). In addition, the spatial characteristics of population migration between the Yangtze River Delta urban agglomeration and the national cities during the Spring Festival travel rush show significant spatial heterogeneity and hierarchical characteristics (Figure 2). Cities in the Yangtze River Delta region and cities in the near region have a close relationship with population migration. The values of the network relationships at the three levels were 17, 363, and 4376, and the scales of the carrying population migration were 2.31, 9.08, and 3.9 million people, respectively. In daily periods, population flow is associated with 35.2 cities on average in the Yangtze River Delta urban agglomeration, and each associated path carries 62,400 people. The scale of daily population flow in Shanghai is 2.16 times that in Suzhou and four times that in Hangzhou and Ningbo, with a prominent siphon effect. In terms of the spatial structure, this also

presents obvious hierarchical characteristics (Figure 3). The numbers of the network relationship at the three levels are 14, 163, and 5746, and the scales of the carrying population flow are 4.75, 3.95, and 3.00 million, respectively. The comparison shows that the number of related cities in the Yangtze River Delta urban agglomeration in the daily period is greater than that during the Spring Festival travel rush, and the radiation scope is wider.

Table 1. Net migration scale of cities in the Yangtze River Delta urban agglomeration (ten thousand people).

A Sequence	City	Net Migration Scale	Flow Scale	A Sequence	City	Net Migration Scale	Flow Scale
1	Shanghai	479.23	509.31	14	Zhoushan	0.12	28.15
2	Suzhou	220.85	235.47	15	Tongling	1.94	22.12
3	Hangzhou	157.93	129.32	16	Hefei	5.13	19.46
4	Ningbo	118.37	123.55	17	Ma'anshan	5.52	18.41
5	Jinhua	86.05	66.57	18	Yangzhou	6.96	18.36
6	Nanjing	72.51	56.35	19	Wuhu	10.58	16.49
7	Wuxi	64.87	48.17	20	Chizhou	13.26	15.62
8	Jiaxing	47.80	45.15	21	Nantong	13.95	15.59
9	Taizhou-ZJ	38.15	44.91	22	Taizhou-JS	14.78	14.11
10	Changzhou	29.34	41.21	23	Xuancheng	23.36	11.12
11	Shaoxing	28.70	37.74	24	Yancheng	26.46	10.65
12	Huzhou	13.90	36.23	25	Chuzhou	45.93	4.86
13	Zhenjiang	4.04	30.82	26	Anqing	60.74	1.42

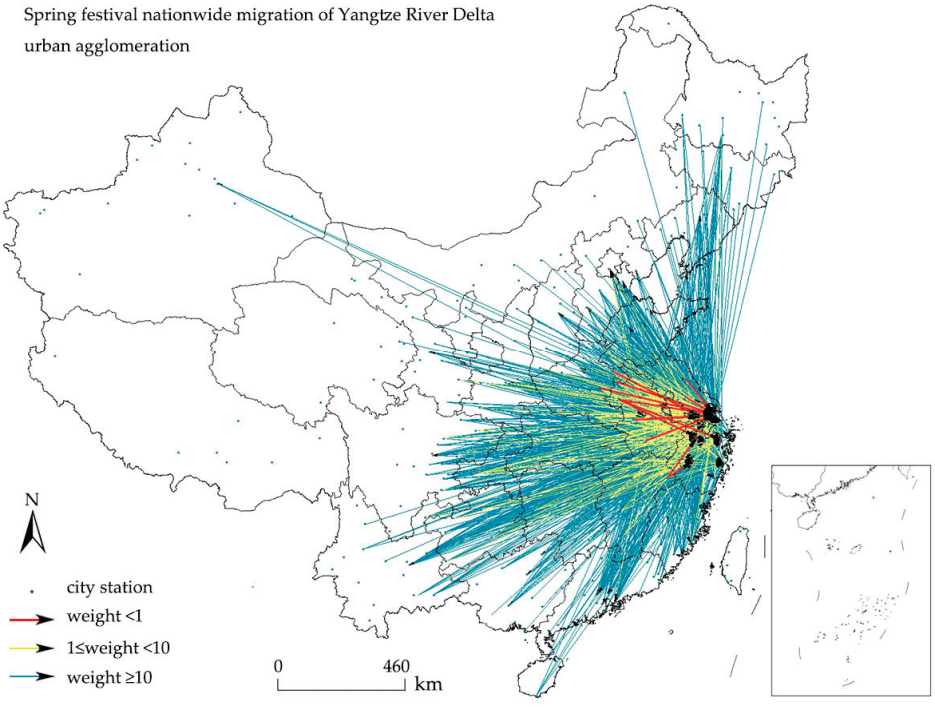


Figure 2. Spatial characteristics of population migration of more than 100 people during the Spring Festival travel rush.

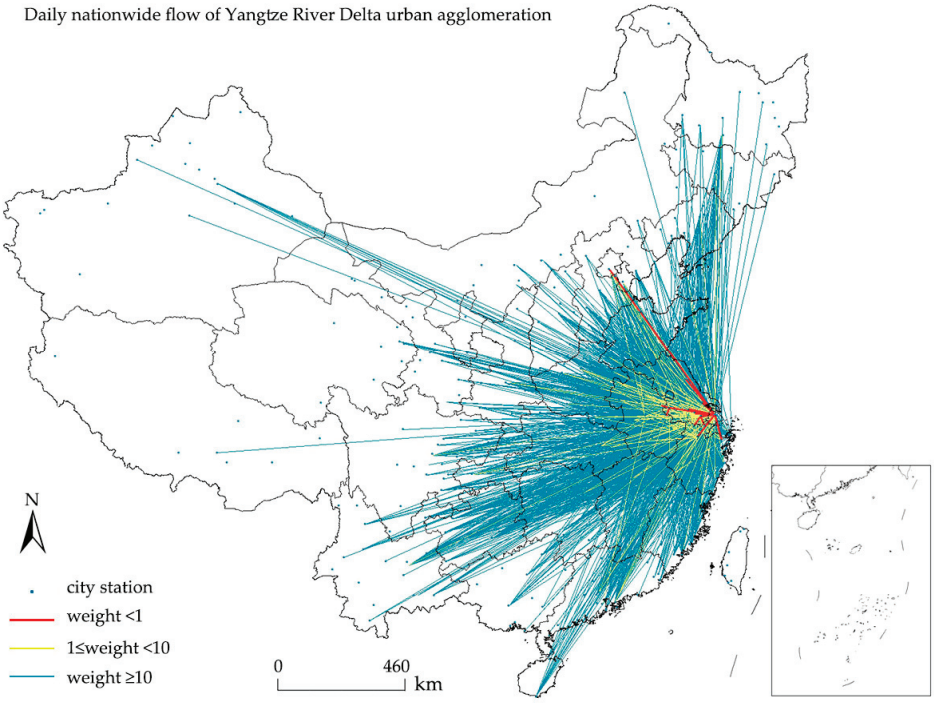


Figure 3. Spatial characteristics of population migration of more than 100 people during the daily travel rush.

3.2. Internal Relationships of Population Resettlement

During the Spring Festival travel rush, the net migration intensity of the population within the Yangtze River Delta urban agglomeration was 2.86 million, forming a total of 230 city-related items. Among them, Shanghai attracted 1.49 million net migrants, accounting for 52.04% of the total. Suzhou and Nanjing gathered 10.61% and 9.45% of the total population, respectively. Hangzhou, Ningbo, Wuxi, and Changzhou attracted a total of 425,100 people from 59 cities. So far, 86.95% of the incoming population has been accumulated in the seven aforementioned cities. Among the top ten population migration flows with the intensity of net migration, seven link people moving into Shanghai, while five link people moving out of Jiangsu and Anhui, respectively (Table 2). Thus, it can be seen that during the Spring Festival travel rush, the net migration intensities of Jiangsu to Shanghai, Anhui to Jiangsu, and Anhui to Shanghai are relatively strong, and the transboundary migration intensity of Zhejiang is relatively small. During the daily period, the population flow intensity within the Yangtze River Delta urban agglomeration was 5.50 million people, and a total of 231 intercity population mobility correlations were formed. There are nine links of population mobility between Shanghai and the cities of Jiangsu province, representing 2.25 million instances of population mobility, accounting for 40.83% of the total mobility in the same period. The scales of population flow across the three inter-provincial boundaries of Shanghai–Zhejiang, Jiangsu–Anhui and Jiangsu–Zhejiang were 0.99, 0.91, and 0.90 million, accounting for 18.09%, 16.70%, and 16.33% of the total, respectively. The population mobility between Zhejiang and Anhui provinces was 229,500 people, accounting for 4.17% of the total scale. Because Anhui province and Shanghai are separated by the Jiangsu and Zhejiang provinces, they are far apart in space, and the population flow is the smallest, with only 213,100 people. Most of the cities in the top ten daily flow intensities are adjacent and belong to provinces (cities) on both

sides of the inter-provincial boundary, indicating that the population flow intensity is affected by the inter-provincial boundary to some extent.

Table 2. Top ten net move-in intensities of Spring Festival and daily flow intensity transport (ten thousand people).

Spring Festival Net Move-In Travel Rush	Intensity	Daily Flow	Intensity
Nantong → Shanghai	20.33	Shanghai–Suzhou	118.96
Yancheng → Shanghai	18.65	Nantong–Shanghai	29.12
Chuzhou → Nanjing	13.17	Jiaxing–Shanghai	28.23
Anqing → Shanghai	11.03	Hangzhou–Shanghai	26.41
Suzhou → Shanghai	10.69	Chuzhou–Nanjing	23.10
Taizhou-JS → Shanghai	10.49	Jiaxing–Suzhou	20.17
Yangzhou → Shanghai	8.09	Shanghai–Wuxi	19.65
Chuzhou → Shanghai	7.61	Ma'anshan–Nanjing	15.23
Anqing → Suzhou	7.13	Nanjing–Shanghai	14.52
Chuzhou → Suzhou	6.88	Ningbo–Shanghai	13.54

By comparing and analyzing the population flow and migration network within the Yangtze River Delta urban agglomeration in two periods (Figure 4), obvious hierarchical characteristics are presented. During the Spring Festival travel rush, there are six first-level population net migration relationships, carrying 0.84 million people, where the migration destinations are Shanghai and Nanjing. There are 56 secondary net migration relationships, carrying 1.64 million people. The destinations include 13 cities, such as Shanghai, Suzhou, and Hangzhou. The 141 third-level population net migration relationships carry 0.38 million people. The destinations include Ningbo, Jiaxing, Wuxi, and another 21 cities. It can be seen that in the net migration network of the Yangtze River Delta urban agglomeration, Shanghai has become the first-level population migration destination, and the second is the Jiangsu province. During daily life, 13 first-level population flows carry 3.43 million people. There are 51 secondary population flows that carry 1.68 million people. The other 154 third-level population flows carry 0.38 million people. During the Spring Festival travel rush, the net migration scale of the three levels of the network accounts for 29.47%, 57.31% and 13.22% of the total migration scale, respectively, and the migration scale of the three levels of the network accounts for 62.42%, 30.62% and 6.95% of the total flow scale, respectively, in the daily period. It can be seen that the secondary network relationship during the Spring Festival travel rush is the main migration path, while the first-level network relationship in the daily stage is the main flow path. The first-level network relationship mainly links Shanghai. As the core city of the Yangtze River Delta urban agglomeration, Shanghai is the most attractive city with the highest level of development and of course the highest cost of living. Almost all of the population migrants during the Spring Festival travel mentioned above are employees from other places. Most of these people represent rural population flows to cities for employment. When choosing a city for employment, these people consider not only employment opportunities and labor benefits, but also the cost of living and the resulting final benefits. Affected by this factor, most migration flows tend to avoid cities such as Shanghai and this has led to secondary network relationships becoming the main migration path.

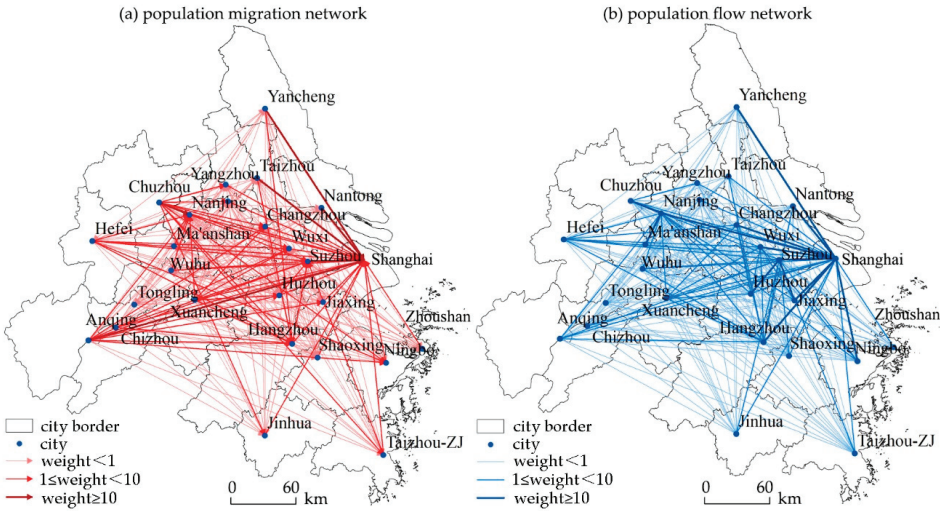


Figure 4. Spatial characteristics of Spring Festival migration (**b**) and daily flow (**a**) in the Yangtze River Delta urban agglomeration.

3.3. Structural Characteristics of Population Flow and Migration Network

During the Spring Festival travel rush, the mean centrality of the net population immigration within the Yangtze River Delta urban agglomeration was 23.08, which means that the 10 cities with net population immigration absorbed an average of 0.23 million people from the Yangtze River Delta urban agglomeration. Shanghai, Nanjing, Suzhou, and Hangzhou rank as the top four for centrality (Table 3). The mean centrality of the net emigration of the population during the Spring Festival travel rush is −14.43, which means the net emigration of the population from the 16 cities in the Yangtze River Delta urban agglomeration is 0.14 million on average. The top four cities are Chuzhou, Anqing, Xuancheng, and Yancheng in terms of the order of centrality. In the daily period, the Yangtze River Delta urban agglomeration's average control force of the network is 42.31, the association hosting an average floating population of 0.42 million for each population flow link, with the top five cities (Shanghai, Suzhou, Nanjing, Hangzhou, and Jiaxing) carrying 65.8% of the total population flow, of which Shanghai represents 31.4% of the daily population flow intensity of the Yangtze River Delta urban agglomeration. By calculation, the network density of the Yangtze River Delta urban agglomeration based on the daily population flow is 0.711, reaching the percolation threshold of 0.5, and the overall network connection shows a strong state of connection. In contrast, the network density is slightly higher than 0.432 in the middle reaches of the Yangtze River [50]. As one of the most developed regions in China, the Yangtze River Delta urban agglomeration has a high degree of inter-city contact, more ways to obtain information and share resources, and a high degree of reciprocity of network resources, basically forming an integrated urban network.

Table 3. Attribute table of city nodes of the population flow and migration network.

City	Related Cities Number	Centricity	Control	City	Related Cities Number	Centricity	Control
Shanghai	25	148.99	345.36	Taizhou-ZJ	18	−4.20	7.68
Nanjing	17	22.68	83.93	Shaoxing	18	−4.40	12.96
Suzhou	17	19.69	178.46	Ma'anshan	18	−5.36	18.02
Hangzhou	18	13.44	59.75	Yangzhou	17	−7.35	15.74
Ningbo	18	8.46	23.24	Wuhu	18	−10.24	12.72
Wuxi	17	7.87	37.32	Chizhou	18	−11.45	3.60
Changzhou	17	3.66	22.47	Taizhou-JS	17	−12.99	12.02
Jiaxing	18	3.38	56.25	Hefei	18	−16.51	25.11
Huzhou	18	2.05	34.03	Nantong	17	−21.39	34.43
Jinhua	18	0.62	10.36	Yancheng	17	−22.50	13.58
Zhenjiang	17	−0.31	8.30	Xuancheng	18	−22.95	27.63
Tongling	18	−1.93	1.32	Anqing	18	−41.65	8.77
Zhoushan	16	−2.62	7.96	Chuzhou	18	−44.97	38.97

Because the density analysis in the social network analysis only focuses on the binary matrix, and as the strength of connection between cities is different, the density analysis can only reflect the characteristics of the urban network to a certain extent. However, "small world analysis" has the feature that most nodes can be reached from any other point through a few correlations, which makes up for the shortage of density analysis. The average clustering coefficient and average path length can reflect whether there is a "small world" effect in the network—that is, how nodes are embedded in their neighbors. The former gives the overall indication of node clustering or agglomeration, and the latter is the average graph distance between all node pairs, where the graph distance of interconnected nodes is 1. If the average clustering coefficient of a graph is significantly higher than the random graph generated by the same number of nodes, and the average shortest path is similar, then the graph is considered to have "small world" characteristics. The average clustering coefficients of the population flow and migration network in the Yangtze River Delta urban agglomeration are 0.290 and 0.583, respectively, both of which are significantly higher than the random network coefficients of 0.029 and 0.058 under the same nodes number. The average path lengths are 1.799 and 1.289, which is close to 1.818 and 1.306. This indicates that there is an obvious "small world" phenomenon in the urban network of the Yangtze River Delta urban agglomeration based on population mobility, and the local network has the characteristics of a cluster structure. Using a modular calculation method (a community detection algorithm [51]) to measure the cities' association in the Spring Festival travel rush and daily period of the Yangtze River Delta urban agglomeration, four and three cluster structures were obtained, respectively (Figure 5). The population migration network of the Spring Festival travel rush includes the central and southern unidirectional cluster of the Yangtze River Delta, the Jiangsu and Anhui inter-provincial boundary cluster, the core–edge cluster in the Yangtze River Delta, and the Zhejiang and Anhui inter-provincial boundary Huzhou–Xuancheng cluster. The daily population flow network forms the Jiangsu and Anhui inter-provincial boundary cluster, boundary cluster of the Jiangsu, Zhejiang, and Anhui provinces, and the core–edge cluster of Yangtze River Delta. These cluster cities have a closer relationship and are geographically closer to each other, which indicates that the urban closeness based on population migration still follows the restriction of the geospatial effect. The core–edge clusters in the Yangtze River Delta are spatially divided by other cluster structures, showing a spatial jump, and are distributed on the east and west sides of the Yangtze River Delta. It can be seen that under the background of flow space, population flow and migration have a tendency to partially overcome spatial friction.

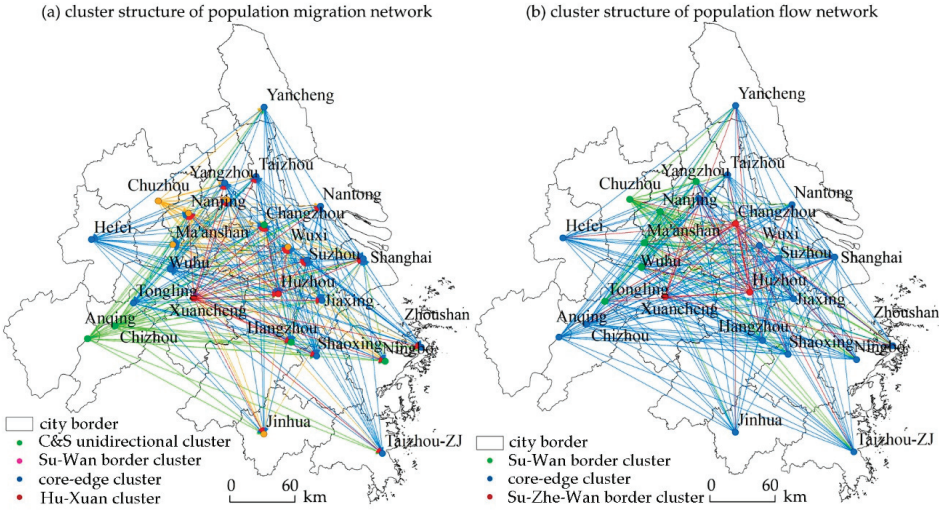


Figure 5. Population flow (**b**) and migration (**a**) network cluster structure diagram of the Yangtze River Delta urban agglomeration.

4. Analysis of Influencing Factors of Network Pattern Formation

4.1. Variable Selection

In the urban network based on population flow and migration, the relationship of the urban network originates from population flow and migration between provinces, so the path selection behavior of population flow and migration constitutes the microfoundation for understanding the urban network correlation pattern. Based on the analysis framework of "behavior-structure-effect", this paper explains the formation mechanism of urban cyberspace pattern in the Yangtze River Delta urban agglomeration. In the analysis framework, the spatial migration behavior of population at the micro level is manifested as the urban connection process with the main characteristics of path selection and path dependence at the macro level. These dynamic processes promote the orderly evolution of an urban network self-organization system and form certain effects. Therefore, the factors influencing the choice of population flow and migration path fundamentally shape the relationship pattern of the urban network. Based on this idea, the following explanatory variables are selected in this paper:

First, the city attribute index. An urban network based on population flow and migration is more dependent on people's subjective mobility consciousness, which involves organizations' tendency to establish ties with other organizations that can make profits for themselves. The assumption is that being an attractive network partner depends on some individual characteristics of the city. In this paper, five indicators were selected as the proxy variables for urban attributes: (1) economic scale (GDP), which is measured by the GDP per capita of permanent residents in the city region (ten thousand yuan). (2) Political resources (capital), which is represented by the dummy variable of the urban administrative level. The value of municipalities directly under the central government, provincial capital cities, and cities with separate plans is 1, while the values of other cities are 0. (3) Employment opportunities (employment) and the unemployment rate (unemployment) are measured by the newly created urban jobs (%) and the registered urban unemployment rate of permanent residents (%), respectively. (4) Labor wage (wage), using the average wage of employees (yuan) for measurement, and (5) the industrial structure (industry), measured by the proportion (%) of the output value of the secondary and tertiary industries in the gross product.

Second, the geospatial index. The geographical location and traffic conditions are the important factors affecting the intensity of population mobility between cities. In this paper, five indicators were

selected as the proxy variables of geographical space: (1) spatial distance (minimum distance), which is measured by the shortest travel distance (km) between each pair of cities, representing the physical distance in the place space (based on Baidu map query, the shortest traffic distance between each pair of cities in the hybrid transportation system of high-speed railway, ordinary railway, expressway, national highway and provincial highway); (2) time distance (minimum time), measured by the shortest travel time (min) between each pair of cities. This is used to represent the network proximity in the flowing space (through Baidu map query, the shortest travel time between each pair of cities (if transfer is needed, the transfer time is included) was obtained based on the above transportation system. In order to ensure the accuracy of the data, the starting and ending points were selected as the main railway stations of each city in the query process. In addition, 12306 and Gaode auto navigation were used to conduct navigation queries on 233 pairs of urban travel to further verify the reliability of the data); (3) shoreline virtual variable (shoreline), where the code of cities along the Yangtze River and coastal cities shall be 1, and the codes of other cities shall be 0; (4) the border area virtual variable (border), where areas located on both sides of the inter-provincial boundary cities code are assigned 1, while other cities are assigned 0 (riverside and coastal cities include the following: Shanghai, Nantong, Suzhou, Yangzhou, Zhenjiang, Nanjing, Wuhu, Tongling, Anqing, Yancheng, Jiaxing, Ningbo, Zhoushan, and Taizhou-ZJ. Cities along the inter-provincial boundary include the following: Shanghai, Suzhou, Jiaxing, Wuxi, Huzhou, Hangzhou, Yangzhou, Nanjing, Changzhou, Chuzhou, Ma'anshan, and Xuancheng); (5) trans-border frequency (trans-border). Here, we use the number of inter-provincial boundaries for each pair of related city populations that are required to go through to travel in the shortest travel time and count 233 associations. The number of border crossings is at least one and at most three. The last three variables are used to capture the influence of explanatory variables that do not change with time and provide a basis for subsequent effect studies.

Third, the network time lag (lag 2010). In the development of an urban network, path dependence (also called preferential attachment [52,53]) is an important driving mechanism. This paper assumes that the growth and development of urban network link relationships are not only affected by the relevant variables of the same period, but also depend on the link relationship pattern formed in history—that is, the habitus of choice of the migration path. In order to capture the influence of early network development foundations on the current network spatial structure, the urban network relationship matrix in 2010 is included in the explanatory variables (since there are no systematic migration data from Baidu in 2010, the floating population data used in this paper are from the data of the sixth census).

4.2. Analysis Results

In the QAP correlation and regression of the directed weighted network in the Spring Festival travel period and the undirected weighted network in the daily period (Table 4), the terms of the economic scale, political resources, employment opportunities, labor wages, industrial structure, virtual variables of the coastal and riverside coastline, virtual variables of the boundary area, and network time lag were all positive and passed the significance test. For example, in the regression analysis of the net migration of the population during the Spring Festival travel rush, the fitting coefficient of employment opportunities was 0.347. In the random rearrangement experiment, the probability P (large) that the fitting coefficient was larger than the actual observed value was 0.025, while the probability P (small) that it was smaller than the actual observed value was 0.975. In the daily population mobility network regression analysis, the fitting coefficient of employment opportunities was 0.405. In the random rearrangement experiment, the probability that the fitting coefficient was greater than the actual observed value was 0.000, while the probability that it was less than the actual observed value was 1.000. The unemployment rate, spatial distance, time distance, and trans-border frequency were all negative values in the regression analysis of the population migration network during the Spring Festival travel rush and the daily population flow network, where neither the unemployment rate nor the spatial distance passed the significance test in the regression analysis of the

population migration network during the Spring Festival. Spatial distance failed the significance test in the regression analysis of the daily population flow network. In a comprehensive sense, 12 factors, including economic scale and spatial distance, explain the poor 85.6% distribution of network link relationships of net migration in the Spring Festival travel rush and the 89.0% value of the floating population for the daily period.

Table 4. Correlation and regression analysis results of quadratic assignment procedure (QAP) matrix.

	Spring Festival Travel Rush				Daily Period			
	R	**Fitting Coefficient**	**P (Large)**	**P (Small)**	**R**	**Fitting Coefficient**	**P (Large)**	**P (Small)**
GDP	0.334 ***	0.057 ***	0.025	0.975	0.368 ***	0.071 ***	0.001	0.999
Capital	0.521 ***	0.067 ***	0.100	0.900	0.454 ***	0.247 **	0.071	0.929
Employment	0.925 ***	0.347 ***	0.025	0.975	0.877 ***	0.405 ***	0.000	1.000
Unemployment	0.209 *	0.262	0.722	0.278	0.255 *	0.068 *	0.075	0.925
Wage	0.763 ***	0.051 ***	0.000	1.000	0.735 ***	0.312 ***	0.000	1.000
Industry	0.393 **	0.030 **	0.065	0.935	0.375 *	0.075 *	0.025	0.975
Minimum distance	0.303 *	0.033	0.724	0.276	0.333 *	0.064	0.866	0.134
Minimum time	0.542 **	0.209 **	0.066	0.934	0.653 ***	0.291 **	0.005	0.995
Shoreline	0.210 **	0.047 **	0.000	1.000	0.226 **	0.051 **	0.000	1.000
Border	0.646 ***	0.174 ***	0.005	0.995	0.652 ***	0.335 ***	0.000	1.000
Transborder	0.196 ***	0.031 ***	0.044	0.946	0.106 ***	0.072 ***	0.022	0.978
Lag2010	0.903 ***	0.799 ***	0.000	1.000	0.839 ***	0.701 **	0.000	1.000
R^2	0.856				0.890			

Note: ***, ** and * represent significance at the levels of 1%, 5%, and 10%, respectively.

First, the economic scale, political resources, and industrial structure are important factors influencing the formation of a population flow and migration network, while employment opportunities and labor wages are key guiding factors for population migration. Through the hypothesis test of the urban attribute and network relationship, it can be concluded that the expected population flows and migration between high–high and low–high per capita GDP cities are significantly lower than the actual values, and the expected population flow and migration between low–low per capita GDP cities is significantly higher than the actual observed value (the judgment of cities with high and low attribute values was based on the following: the average value of the attribute value was taken as the truncation value. Cities whose actual attribute value was higher than the truncation value were determined as the "high" type. Cities whose actual attribute value was lower than the truncation value were determined as the "low" type). The hypothesis test of the relationship between political resources, industrial structure, and the network presents similar characteristics. The correlation analysis results of the QAP for employment opportunities, labor wages, and network relationships show correlation coefficients between 0.735 and 0.925 and all passed the test of significance here, with highest relevance in the city property index of the six variables, which can provide a key population flow moving direction selection guide. The expected value of population migration between cities with high–high and low–high employment opportunities is significantly lower than the actual observed value, and the expected value of population migration between cities with low–low employment opportunities is significantly higher than the actual observed value; the characteristics of the hypothesis testing results of labor wage and network relationship are the same as above. Although the unemployment rate has a negative impact on the net population migration, it does not constitute the main factor affecting the population flow and migration because it does not pass the significance test of regression analysis. The results show that cities with a large economic scale, rich political resources, and high degree of industrial structure optimization are conducive to promoting population flow and migration. In addition, cities with more employment opportunities and high labor wages are conducive to attracting flow and migration.

Secondly, the spatial distance and time distance are conditional factors that affect the formation of population flow and migration networks. Among them, the QAP correlation analysis results of the time

distance and network relationship all pass the significance testing, while only the Pearson correlation coefficient and gamma value of the correlation analysis results for the spatial distance and network relationship pass the significance testing, indicating that time distance has a more significant impact on the network spatial pattern of population migration. In the hypothesis test between time distance and network relationship, the expected value of population flow between cities with a short time distance was significantly lower than the actual observed value, while the expected value of population flow and migration between cities with long time distance was significantly higher than the actual observed value. Shoreline cities along the river (sea) and border area cities are beneficial to forming closely linked relationships with the population flow. The hypothesis test between these cities and the network relationship shows that shoreline cities along the river (sea) and border area cities have population flow expectations that are significantly lower than the observed values. However, other population flow values for cities that are near the expected value are significantly higher than the observed values. The QAP correlation analysis shows that in the geographic spatial index, the boundary region has the most significant influence on the formation of the network spatial pattern of population migration. According to the statistics here, in the 233 pairs of population flow and migration, the trans-border frequency is restricted by the spatial distance and time distance and has a certain negative influence on population resettlement. The results show that the inter-provincial boundary plays a dominant role in the development of the inter-provincial population flow and migration network relationship. Under the multiple influences of the spatial distance, time distance, and trans-border frequency, whether the optimal path can break through the inter-provincial boundary becomes the decisive factor for the formation of the spatial pattern of the population flow and migration network.

Thirdly, the "inertia flow and migration" caused by the historical basis has a profound influence on the formation and development of the population flow and migration network. The QAP correlation analysis results of the network relationship in 2010 and 2015 show that the correlation coefficient and other participating fitting values are positive and pass the significance test, and the correlation between them is robust. Cities with more linked relationships in history tend to further enhance the strength of said linked relationships, while those without an active population flow and migration history still have fewer link relationships. This indicates that the mechanism of cyclic accumulation is a causal relationship and is an important basis for linked relationships in population migration networks, which leads to the characteristics of path dependence and self-reinforcement in the development of the network patterns. However, the scale and strength sequences of population mobility links in 2010 and 2015 do not correspond completely here, indicating the dynamic nature of urban competitiveness and the inter-city population flow relationship, as well as the complexity of the evolutionary dynamic mechanism of urban network relationships.

5. Conclusions and Discussion

5.1. Conclusions

Migration data based on the measured flow and migration data of Baidu for the Yangtze River Delta urban agglomeration during the Spring Festival and daily period were used here, analyzing the characteristics and the network structure. Three factors were introduced, including inter-provincial borders, the trans-border frequency, and time distance, which are embedded in traditional network pattern influencing factors. We have discussed the formation of the Yangtze River Delta urban agglomeration's population flow and migration network structure mechanisms; relevant conclusions include the following:

(1) During the Spring Festival travel rush, Shanghai, as a central city, has a significant siphon effect, with Suzhou, Nanjing, Hangzhou, Ningbo, Wuxi, and Changzhou gathering 86.95% of the incoming population. The net migration intensity of Jiangsu to Shanghai, Anhui to Jiangsu, and Anhui to Shanghai was stronger, and the transboundary migration intensity of Zhejiang Province was relatively small. In the daily period, the cross-border population mobility between Shanghai and other

provinces accounted for 40.83% of the total scale of the same period. Most of the top ten associated cities in terms of flow intensity are located adjacent to each other, and they belong to provinces (cities) on both sides of the inter-provincial boundary, indicating that the population mobility intensity is affected by the inter-provincial boundary to a certain extent. The population migration network has obvious hierarchical characteristics. During the Spring Festival travel rush, the secondary network relationship is the main migration path, while the first-level network relationship in the daily stage is the main migration path. This shows that the daily population flow has a significant core spatial agglomeration effect, but the migrant population, who are employed in different places, takes into account the decline in the total employment income caused by the cost of living, and often avoids the first-level network relationship and chooses to move into the secondary core of the urban agglomeration to seek employment opportunities through the secondary network relationship. (2) The values of the network density, mean centrality, and the average control force indices were 0.711, 23.08, and 42.31, and they all show that the Yangtze River Delta urban agglomeration network, based on population flow and migration, presents a strong state of connection. In addition, the calculation results of the average clustering coefficient and average path length of the network nodes show that there is an obvious "small world" phenomenon in the population flow and migration network of the Yangtze River Delta urban agglomeration, and that cluster structure characteristics are formed locally in the network. Using a modular calculation method to measure the Spring Festival travel and daily association, four and three cluster structures were obtained, respectively. Among them, the central and southern parts feature a unidirectional cluster, with a Jiangsu and Anhui inter-provincial boundary cluster, Zhejiang and Anhui inter-provincial boundary Huzhou–Xuancheng cluster, and Jiangsu, Zhejiang, and Anhui inter-provincial boundary cluster. These cities have a closer relationship and are geographically closer to each other, which indicates that the urban closeness based on population migration still follows the geospatial restriction effect. Core-edge clusters are spatially divided by other cluster structures, showing a spatial jump, and are distributed on the east and west sides of the Yangtze River Delta. It can be seen that against the background of flow space, population migration has a tendency to partially overcome spatial friction. (3) Among the traditional factors, economic scale, political resources, and industrial structure are the important influencing factors for the formation of population flows and migration networks, while employment opportunities and labor wages are the key guiding factors for population flow and migration. Spatial distance is a conditional factor that affects the formation of population flows and migration networks. The "inertia flow and migration" caused by a historical basis has a profound influence on the formation and development of population flows and migration networks. The innovatively introduced boundary region variable has a significant positive influence on the pattern of population flow and migration in cyberspace. The degree of influence even exceeds traditional factors such as the economic scale and political resources, and the relevance is second only to employment opportunities and labor income. Due to the restriction of the spatial distance and time distance, the transboundary frequency has a certain negative influence on the network pattern of population flow and migration. The influence of the time distance on the spatial pattern of population flow and migration network is greater than that of the spatial distance, which is a conditional factor that affects the formation of population flows and migration networks. Therefore, the inter-provincial boundary plays a leading role in the development of the inter-provincial flow and migration network relationship. Under the multiple influences of the spatial distance, time distance and trans-border frequency, whether the optimal path can break through the inter-provincial boundary becomes the decisive factor for the formation of a spatial pattern for population flows and migration networks.

5.2. Discuss

On the basis of traditional urban network structure influence factors, this paper has introduced three factors, including the time distance, inter-provincial administrative boundary (because of China's special administrative divisions), and trans-border frequency, to quantitatively analyze the Yangtze River Delta urban agglomeration in terms of the population flow and migration network pattern

formation, as well as the impact of the development process. We have also explained the mechanism of action. This not only enriches the factors that influence the formation and development of a network structure, but also verifies the rationality and necessity of adding new factors through matrix correlation and regression analyses to prove the objectivity of the relationship between the urban network and inter-provincial boundary, which means that there is no "false relationship" in terms of statistical significance. The disadvantage is that this paper confirms that the inter-provincial boundary plays a leading role in the formation and development of the inter-provincial population flow and migration network relationship, but it has not yet discussed the boundary effect in the urban network structure in terms of the flow and migration behavior, which will be one of the focuses of follow-up research. In addition, this article has analyzed the population migration network patterns and causes of the Yangtze River Delta urban agglomeration in a specific year, while multi-space, multi-scale, and multi-temporal comparative studies have not yet been performed. Currently, Xuewei Wang is leading a team to conduct related research, including a comparative study of the population migration network patterns and causes of the three major urban agglomerations of the Yangtze River Delta, central China, and Chengdu–Chongqing in the Yangtze River Economic Belt, as well as an analysis of the 2020 Spring Festival and daily population migration and flow patterns. For now, the preliminary results show that there are certain differences in the patterns of population migration networks in different regions and that the impact of factor groups is also different. In addition, due to the impact of coronavirus, introducing an era of pandemic crises, network patterns and influencing factor analysis based on the data from February to April in 2020 show significant abnormalities, indicating that, during a pandemic, the formation and development factors of the population migration network need to be further improved.

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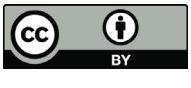
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References

1. Wang, S.J.; Lian, C.; Zhao, Z.Y. From central place to city network: A theoretical change in China's urban system study. *Geogr. Res.* **2019**, *38*, 64–74. (In Chinese)
2. Luthi, S.; Thierstein, A.; Hoyler, M. The world city network: Evaluating top-down versus bottom-up approaches. *Cities* **2018**, *72*, 287–294. [CrossRef]
3. Fang, C.L.; Qi, W.F.; Song, J.T. Researches on comprehensive measurement of compactness of urban agglomerations in China. *Acta Geogr. Sin.* **2008**, *63*, 1011–1021. (In Chinese)
4. Song, J.T.; Fang, C.L.; Song, D.J. Spatial structure stability of urban agglomerations in China. *Acta Geogr. Sin.* **2006**, *61*, 1311–1325. (In Chinese)
5. Li, Y.T.; Pan, S.Q.; Miao, C.H. Structure and evolution of economic linkage network at county level in Central Plains Economic Zone. *Geogr. Res.* **2014**, *33*, 1239–1250. (In Chinese)
6. Li, W.M.; Chai, Z.Y.; Jiang, J.Y. Structural Characteristics in Central Zhejiang Urban Agglomeration Based on Spatial Elements System Analysis. *Sci. Geogr. Sin.* **2011**, *31*, 295–301. (In Chinese)
7. Xue, B.; Zhang, L.M.; Geng, Y.; Ren, W.X.; Lu, C.P.; Tian, X. Spatial-restructuring Analysis of Human-land Relationships in An Old Industrial Area: The Case of the Tiexi District, Shenyang. *Sci. Geogr. Sin.* **2015**, *35*, 890–897. (In Chinese)
8. Shi, Y.J.; Zhu, Y.B.; Feng, D.X.; Wang, F.Z.; Xiong, W. Polycentric Network Development Pattern of Zhongyuan Urban Agglomeration. *Sci. Geogr. Sin.* **2012**, *32*, 1431–1438. (In Chinese)
9. Chen, Y.G.; Zhang, C.; Wu, Y. Proximities and knowledge spillover in the Yangtze River Delta urban development studies. *Urban Dev. Stud.* **2018**, *25*, 34–44. (In Chinese)

10. Chen, X.F. Analysis on the synergistic agglomeration effect of producer service industry and manufacturing industry: A case of Yangtze River Delta. *Urban Probl.* **2016**, *12*, 63–70. (In Chinese)
11. Ma, S.; Zeng, G. Regional innovation models of China's ten major urban agglomerations from the perspective of network. *Sci. Geogr. Sin.* **2019**, *39*, 905–911. (In Chinese)
12. Li, Q.J. Research on deep transformation of industrial isomorphism in Yangtze River Delta. *Shanghai J. Econ.* **2006**, *4*, 47–56. (In Chinese)
13. Li, W.; Wang, X. Towards a mega-regional economy: A financial geography perspective to understanding Shanghai's role in the Yangtze River Delta integration. *Geoforum* **2019**, *101*, 1–9. [CrossRef]
14. Wang, S.; Wang, J.; Liu, X. How do urban spatial structures evolution in the high-speed rail era? Case study of Yangtze River Delta, China. *Habitat Int.* **2019**, *93*, 102–105. [CrossRef]
15. Ouyang, X.; Gao, B.; Du, K.; Du, G. Industrial sectors' energy rebound effect: A empirical study of Yangtze River Delta urban agglomeration. *Energy* **2018**, *145*, 408–416. [CrossRef]
16. Yao, S.M.; Zhu, Y.M.; Chen, Z.G. *China's Urban Agglomeration*; University of Science and Technology of China Press: Hefei, China, 2001. (In Chinese)
17. Shi, Y.W.; Li, E.L.; Li, X.J. Impact of geographical proximity and relational proximity on innovation in agriculture industrial cluster based on the Shouguang vegetable industrial cluster. *Sci. Geogr. Sin.* **2016**, *36*, 751–759. (In Chinese)
18. Gorodnichenko, Y.; Linda, T. Border Effect or Country Effect? Seattle May Not Be So Far from Vancouver After All. *Am. Econ. J. Macroecon.* **2009**, *1*, 219–241. [CrossRef]
19. Borraz, F.; Cavallo, A.; Rigobon, R.; Zipitria, L. Distance and political boundaries: Estimating border effects under inequality constraints. *Int. J. Financ. Econ.* **2016**, *21*, 3–35. [CrossRef]
20. Guo, X.H.; Wang, L.Q. Boundary effects and the study of Yangtze River Delta economic integration. *Stat. Inf. Forum* **2012**, *5*, 66–70. (In Chinese)
21. Dzvid, C.P.; Shang, J.W. Explaining the border effect: The role of exchange rate variability, shipping costs, and geography. *J. Int. Econ.* **2001**, *10*, 87–105.
22. Morshed, A. What can we learn from a large border effect in developing countries? *J. Dev. Econ.* **2003**, *72*, 353–369. [CrossRef]
23. Subhayu, B.; Sajal, L.; Howard, J. Cross-border lobbying in preferential trading agreements: Implications for external tariffs and welfare. *Rev. Int. Econ.* **2012**, *20*, 1034–1045.
24. Natalie, C. Intra-national versus international trade in the European Union: Why do national border matter? *J. Int. Econ.* **2004**, *13*, 93–118.
25. Sousa, J.D.; Lochard, J. Do currency barriers solve border effect puzzle? Evidence from the CFA franc zone. *Rev. World Econ.* **2005**, *141*, 422–441. [CrossRef]
26. Brandon, J.; Youngsuk, Y. Policy uncertainty, irreversibility, and cross-border flows of capital. *J. Int. Econ.* **2016**, *103*, 13–26.
27. Kovács, Z. Border changes and their effect on the structure of Hungarian society. *Political Geogr. Q.* **1989**, *8*, 79–86. [CrossRef]
28. Yu, B.; Liu, M.H.; Zhu, L.X.; Gao, J.B.; Zeng, J.X. The border effect and the development of border region between conurbations. *Sci. Geogr. Sin.* **2012**, *32*, 666–672. (In Chinese)
29. Helble, M. Border effect estimates for France and Germany combining international trade and intranational transport flows. *Rev. World Econ.* **2007**, *143*, 433–463. [CrossRef]
30. Olper, A.; Raimondi, V. Agricultural market integration in the OECD: A gravity-border effect approach. *Food Policy* **2008**, *33*, 165–175. [CrossRef]
31. Head, K.; Mayer, T. Non-Europe: The magnitude and causes of market fragmentation in the EU. *Rev. World Econ.* **2000**, *136*, 284–314. [CrossRef]
32. McCallum, J. National borders matter: Canada—U.S. regional trade patterns. *Am. Econ. Rev.* **1995**, *85*, 615–623.
33. Helliwell, J.F. National borders, trade and migration. *Pac. Econ. Rev.* **1997**, *2*, 165–185. [CrossRef]
34. Nuria, G.; Carlos, L. The border effect and the nonlinear relationship between trade and distance. *Rev. Int. Econ.* **2014**, *22*, 1016–1048.
35. Engel, C.; Rogers, J.H. How wide is the border? *Am. Econ. Rev.* **1996**, *86*, 1112–1125.
36. Hazledine, T. Border effects for domestic and international Canadian passenger air travel. *J. Air Transp. Manag.* **2009**, *15*, 7–13. [CrossRef]

37. Wang, C.L.; Liu, H.; Zhang, M.T. Progress and prospects of border research. *Prog. Geogr.* **2016**, *35*, 1109–1118. (In Chinese)
38. Anderson, J.E.; Wincoop, E.V. Gravity with gravitas: A solution to the border puzzle. *Boston Coll. Work. Pap. Econ.* **2001**, *93*, 170–192.
39. Tang, J.Z.; Zhang, B.; Chen, Y. The boundary effect and cross-border subregional economic cooperation: A case study of East Asia. *Hum. Geogr.* **2002**, *17*, 8–12. (In Chinese)
40. Li, T.; Jiang, H.Y. The research on mechanism of sub-regional economic cooperation: An analyzing framework from the view of border-affect. *Northeast Asia Forum* **2005**, *14*, 90–94. (In Chinese)
41. Zhu, Y.; Lin, L.Y. Studies on the temporal processes of migration and their spatial effects in China: Progress and prospect. *Sci. Geogr. Sin.* **2016**, *36*, 820–828. (In Chinese)
42. Zhao, Z.Y.; Wei, Y.; Pang, R.Q.; Wang, S.; Feng, Z. Alter-based centrality and power of Chinese city network using inter-provincial population flow. *Acta Geogr. Sin.* **2017**, *72*, 1032–1048. (In Chinese)
43. Ye, J.Z. Stayers in China's "hollowed–out" villages: A counter narrative on massive rural-urban migration. *Popul. Space Place* **2017**, *24*, 2128–2133. [CrossRef]
44. Lai, J.B.; Pan, J.H. Spatial pattern of population flow among cities in China during the Spring Festival travel rush based on "tencent migration" data. *Hum. Geogr.* **2019**, *34*, 108–117. (In Chinese)
45. Zhao, Z.Y.; Wei, Y.; Pang, R.Q.; Yang, R.; Wang, S.J. Spatiotemporal and structural characteristics of interprovincial population flow during the 2015 Spring Festival travel rush. *Prog. Geogr.* **2017**, *36*, 952–964. (In Chinese)
46. Zhao, Z.Y.; Wei, Y.; Yang, R.; Wang, S.J.; Zhu, Y. Gravity model coefficient calibration and error estimation: Based on Chinese interprovincial population flow. *Acta Geogr. Sin.* **2019**, *74*, 203–221. (In Chinese)
47. Ebenstein, A.; Zhao, Y. Tracking rural-to-urban migration in China: Lessons from the 2005 inter-census population survey. *Popul. Stud.* **2015**, *69*, 1–17. [CrossRef]
48. Liu, Y.; Liu, X.; Gao, S.; Gong, L.; Kang, C.; Zhi, Y.; Chi, G.; Li, S. Social sensing: A new approach to understanding our socioeconomic environments. *Ann. Assoc. Am. Geogr.* **2015**, *105*, 512–530. [CrossRef]
49. Lu, Y.; Liu, Y. Pervasive location acquisition technologies: Opportunities and challenges for geospatial studies. *Comput. Environ. Urban Syst.* **2012**, *36*, 105–108. [CrossRef]
50. Ye, Q.; Zhang, L.X.; Peng, P.; Huang, J.L. Research on network characteristics of urban agglomeration in the Middle Yangtze River based on Baidu migration data. *Econ. Geogr.* **2017**, *37*, 53–59. (In Chinese)
51. Blondel, V.D.; Guillaume, J.L.; Lambiotte, R.; Lefebvre, E. Fast unfolding of communities in large networks. *J. Stat. Mech.* **2008**, *2008*, 155–168. [CrossRef]
52. Sheng, K.R.; Yang, Y.; Zhang, H.X. Cohesive subgroups and underlying factors in the urban network in China. *Geogr. Res.* **2019**, *38*, 2639–2652. (In Chinese)
53. Liu, X.; Derudder, B.; Liu, Y. Regional geographies of intercity corporate networks: The use of exponential random graph models to assess regional network formation. *Pap. Reg. Sci.* **2015**, *94*, 109–126.



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