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Demographics and Regional Economic Development

Edited by
Kostas Rontos

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Guest Editor

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About the Editor

Kostas Rontos

Kostas Rontos received his degree in Economics from the National and Kapodistrian University of Athens and completed postgraduate studies in Regional Development at Panteion University of Social and Political Sciences. He holds a Ph.D. in Demographic Statistics and Regional Demography from Panteion University and conducted postdoctoral research at the London School of Economics and Political Science on the evaluation of community infrastructure projects in European Mediterranean regions. He served as Professor of Social Demography and Statistics in the Department of Sociology at the University of the Aegean until August 2022, teaching courses in Statistics, Social Demography, Regional Social Analysis, Quantitative Methods in the Social Sciences, and Social Research Methodology. He is currently an expert affiliated with "Population Europe," the leading European demographic research network. From 1981 to 2005, he worked at the National Statistical Service of Greece, where he eventually served as Director. He has coordinated or contributed to 58 research projects related to primary social survey design, statistical systems, socio-economic and regional analysis, labor market and enterprise studies, institutional economics, demographic and social policy evaluation, and migration and refugee research. He is the author or co-author of 264 publications, including journal articles, books, collective volumes, and conference proceedings, several of which appear in high-ranking international journals (Q1–Q2, Scimago). His research interests include Statistics and Demography, Regional Development and Migration, Socio-Economic Analysis, and Information Systems.

Preface

This Reprint is the result of a collaborative effort by scientists from diverse regions of the world, aiming to highlight the relationships and interdependencies between demographic factors and economic development at both local and regional levels. The motivation for this work lies in the need to illuminate these critical issues and to propose scientifically grounded solutions—through empirical research and analytical models—that can support policies designed to improve the living conditions of modern societies. Ultimately, the goal is to contribute to a fairer distribution of resources and to reduce the challenges faced by communities, particularly at the regional and local levels.

It should be emphasized that the analyses and proposals presented in this Reprint are not limited to the specific areas examined. Rather, they are relevant to other regions confronting similar challenges, thereby broadening the applicability and enhancing the value of this publication. In this sense, the Reprint can serve as a useful resource for scholars, educators, and policymakers seeking to advance and disseminate knowledge—a process that fosters social and economic progress.

Overall, I believe that this Reprint constitutes a significant contribution to the systematic exploration of critical contemporary issues in research and science, and to the formulation of policies capable of addressing them effectively.

Kostas Rontos
Guest Editor

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Editorial

Demographic Trends and Regional Development

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The contemporary evolution of scientific thought and research is increasingly characterized by efforts to investigate and address problems whose origins extend over long historical periods, often spanning several decades. Among these problems, regional inequalities at multiple spatial and social levels occupy a central position (Petrakos et al., 2023; Rontos et al., 2023; Toth & Nagy, 2023; Schenone et al., 2025). These disparities have become progressively more pronounced due to the persistent unequal distribution of wealth and the uneven access to technology and knowledge—conditions shaped by the productive structures and social relations of the modern capitalist system and the processes of globalization. It is further noted that economic inequalities are closely intertwined with social inequalities, which continue to sustain recurring crises of longer duration than in the past, especially where levels of social cohesion and social capital are comparatively weaker (Rontos et al., 2022).

Economic development is therefore not solely associated with an increase in production. Rather, it is linked to the sustainability of development trajectories, the integration of social development into the broader concept of progress, the preservation of natural resources, and the equitable distribution of developmental benefits. It also requires balancing urban and rural development, maintaining a resilient workforce and a well-functioning local labor market, and safeguarding agricultural production to ensure food security—particularly in disadvantaged regions affected by resource scarcity or geopolitical instability.

Demographic trends are also unfavorable, especially in the Western world. Indeed, in many Western countries demographic developments have become increasingly unfavorable, undermining dynamic economic growth and, in the long term, the viability of affected societies. The inability of countries such as Greece, along with many other European countries, to stabilize and increase their population size and raise fertility levels over recent decades has resulted in depopulation, persistently low birth rates, and accelerated population aging. Without the inflow of migrants and refugees from third countries, the extent of both the quantitative and qualitative demographic decline would be even greater. Under these conditions, demographic policy has often proven inadequate, fragmented, and short-sighted.

The interdependence between demographic and economic development is particularly evident at the regional and local levels, where inequalities between advantaged and disadvantaged areas become most visible. The roots of demographic decline are primarily socio-economic, and a shrinking or aging population cannot serve as a foundation for sustained development.

The evolution of demographic components—fertility, mortality, and migration—is closely linked to broader social and economic structures, as captured in the widely applied demographic transition model. According to this model, birth and death rates decline gradually through a series of five phases as living standards rise, health conditions improve, and social norms regarding gender roles, marriage, and family size undergo significant changes.

A decline in births within a given geographical area may occur either because the number of individuals of reproductive age diminishes or because fertility levels decline among those who remain. For instance, the large-scale post-war migration from Greece to overseas destinations and Western Europe significantly reduced the size of reproductive-age cohorts; between 1961 and 1977, 1,044,753 permanent and 1,075,007 temporary migrants—largely young adults—left the country (Rontos et al., 2024a). From the perspective of fertility, a major structural cause of decline is the transition from rural, agrarian societies to industrial and urbanized ones. This transition transformed the role of the traditional family, reducing the social and religious pressures—especially on women—to marry early and have multiple children. As a result, modern demographic patterns emerged, characterized by declining marriage and birth rates, rising divorce rates, and increased migration from less developed to more developed countries.

Secondary factors associated with industrial and post-industrial societies further constrain fertility. These include the changing roles of women, extended participation of young adults in education, the near-universal integration of women into the labor market, and the rise in individualism and consumerism, which discourage the assumption of long-term familial obligations at younger ages. Recent labor market instability, which limits young people's access to stable and secure employment, constitutes an additional barrier to marriage and childbearing. The postponement of childbearing into one's thirties also creates biological constraints. In contexts where family and fertility policies are insufficient, inconsistent, or poorly targeted, demographic problems persist and intensify (Reynolds & Mansfield, 1999; Oinonen, 2004; Rontos et al., 2024b).

The continued deterioration of demographic conditions gradually leads to social regression and economic stagnation as workforce renewal becomes increasingly difficult; social insurance systems face structural challenges; and public infrastructures such as education and health services are underutilized, increasing per capita costs. Local resources, particularly in rural and remote areas, are abandoned; returns on investment decline; technological capabilities weaken; and national defense capacities may be reduced. Over the long term, opportunities for innovation, technological advancement, and the introduction of new ideas diminish as these processes depend heavily on the presence and dynamism of younger generations. The negative interaction between demographic decline and economic underdevelopment operates cumulatively and cyclically.

Against this broader backdrop, the present reprint aims to illuminate the interdependence between demographic evolution and regional development across diverse geographic contexts. The included articles employ contemporary demographic analysis alongside methods from regional science to examine demographic challenges and economic prospects in the regions studied. Their objective is to inform policy interventions capable of addressing local needs and enhancing societal well-being.

Specifically, the contributions examine the need for a transition from traditional economic development models to frameworks emphasizing socio-environmental sustainability; analyze the population structure of Greece at the local level and the corresponding need for policies to reduce inequalities; investigate regional labor force disparities in West Virginia, USA; assess the impact of demographic change on the sectoral structure of economic activity in Greece; explore the relationship between regional accessibility and population change in Italian communities; analyze the connections between urban sprawl and economic development in the Athens Metropolitan Area; present a regional input–output analysis of Thailand's tourism system influenced by COVID-19; and examine the threat of water scarcity to food security in the Euphrates–Tigris River Basin in the Middle East.

The thematic diversity and geographical breadth of these studies—spanning both developed and less developed regions—offer representative examples of the demographic and economic challenges confronting contemporary societies. They also provide policy models and proposals that may be applicable not only to the regions examined but also to other areas experiencing similar problems.

Conflicts of Interest: The author declares no conflicts of interest.

References

Oinonen, E. (2004). Starting the first family. *European Societies*, *6*(3), 319–346. [CrossRef]

Petrakos, G., Rontos, K., Salvati, L., Vavoura, C., & Vavouras, I. (2023). Income inequality in the over-indebted eurozone countries and the role of the excessive deficit procedure. *Open Economies Review*, *35*(2), 301–322. [CrossRef]

Reynolds, J., & Mansfield, P. (1999). The effect of changing attitudes to marriage on its stability. In *High divorce rates: The state of the evidence on reasons and remedies* (Vol. 1). Lord Chancellor's Department.

Rontos, K., Ermini, B., & Salvati, L. (2022). Enlarging the divide? Per-capita income as a measure of social inequalities in a southern european city. *Quality and Quantity*, *57*(1), 345–361. [CrossRef] [PubMed]

Rontos, K., Kontogiannis, G., Salvati, L., & Antonoglou, D. (2024a). Demographic change and beliefs towards marriage: Exploring the associated factors in urban and rural Greece before and during recession. In L. Salvati (Ed.), *Environmental sustainability and global change*. Elsevier.

Rontos, K., Salvati, L., & Ermini, B. (2024b). Population contexts, economic crisis, and the non-demographic policy implementation in Greece. In M. Clemente, J.-R. Comino, & F. Chelli (Eds.), *Resilient landscapes: Post-crisis local development and sustainable society*. CRC and Routledge.

Rontos, K., Syrmali, M.-E., Salvati, L., & Vavouras, I. (2023). Competitiveness, corruption and income inequalities: Approaching the 'janus' face of development with simultaneous equation modelling. *Quality & Quantity*, *58*(1), 343–364. [CrossRef]

Schenone, M. B., Tomaselli, V., & Vichi, M. (2025). Uncovering socioeconomic disparities in European regions: A Tucker 3 clustering approach. *Quality and Quantity*. [CrossRef]

Toth, G., & Nagy, Z. (2023). An analysis of federal income inequality in the United States, 1917–2018. *Regional Statistics*, *13*(5), 973–994. [CrossRef]

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Article

Revisiting the Spatial Cycle: Intra-Regional Development Patterns and Future Population Dynamics in Metropolitan Athens, Greece

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Abstract: Being intertwined with economic development, urbanization determines the present and future development path of regions and countries. The intimate relationship between urban expansion and economic development is of particular interest in the case of large regions with complex (and mostly non-linear) socio-demographic dynamics and a relevant primacy in the metropolitan system of a given country. Typical examples of advanced economies with settlement systems characterized by a high degree of city primacy are peripheral and disadvantaged European countries such as Portugal and Greece. For instance, the administrative region of Attica—centered on Athens, the Greek capital city—represents the largest metropolitan area of the country, hosting almost 3.8 million inhabitants in 2021 (36.2% of the Greek population). In this context, this study investigates the internal redistribution of the resident population in metropolitan Athens and the progressive development of satellite cities over a relatively longtime interval, testing the assumptions of the Spatial Cycle Theory (SCT) between 1951 and 2021 and predicting future development paths up to 2051. To investigate past, present, and future intra-regional population trends, we used data released from decadal (1951–2021) censuses and demographic forecasts for the years 2031, 2041, and 2051. Being in line with the SCT, the empirical results of our study document how demographic dynamics of individual centers influence largely—and independently—the long-term development of metropolitan regions, both with policy/planning regulation and in conditions of non-intervention (spontaneous urban growth).

Keywords: urban growth; economic cycle; immigration; satellite cities; Southern Europe

1. Introduction

A growing population in cities is the joint result of natural population growth and (internal and international) immigration to urban areas (Haase et al. 2013). A multitude of socioeconomic drivers and, likely more surprisingly, exogenous shocks that were hardly predicted (e.g., wars, economic recessions, climate crises, pandemics) have influenced such socio-demographic processes (Fielding 1982). Urbanization thus constitutes a complex phenomenon intertwined with long-term development processes characteristic of any country in the world (Findley 1993; Henderson 2003a; Niu et al. 2021). In this perspective, urban expansion should not be regarded as a one-dimensional process (Black and Henderson 2003; Bai et al. 2012; Chen et al. 2014), reflecting long-term population redistribution paths with different intensities and spatial directions across metropolitan regions (e.g., Champion 1989; Cross 1990; Salvati et al. 2019). They include a relatively fast population growth in urban areas and the subsequent decline of the resident population in the densest settlements (Henderson 2003b; Shaban et al. 2022; Antonoglou and Rontos 2023b). The Spatial Cycle Theory (SCT), initially proposed by Klaassen (1981) and further developed by van de Berg et al. (1982), aims at identifying and explaining sequential development stages of cities in relation to their wider region of influence (namely, metropolitan regions or functional urban areas). Based on SCT assumptions, urban areas are assumed to evolve according to sequential stages, as follows:

- 'Urbanization': settlements develop at the expense of the surrounding rural space;
- 'Suburbanization': suburban settlements develop at the expense of urban cores;
- 'Disurbanization': urban populations decentralized towards satellite centers;
- 'Reurbanization': population in central locations start growing again after a long decline.

In the first stage, population and economic activities concentrate in central locations, forming dense and compact cities (Angel et al. 2011; Turok and McGranahan 2013; Li et al. 2021). The expansion of secondary and tertiary sectors downtown, alongside the consolidation of the primary sector in peripheral locations, creates the conditions at the base of the first stage of the SCT, namely, 'urbanization' (Champion 2000). The promotion and adoption of new economic standards and the attractive force of neighboring cities—in turn shaped by external economies, infrastructure, and institutional factors—may consolidate this development stage (Ji et al. 2020). With the inherent concentration of the population and economic activities downtown, negative external economies begin to swell, and severe traffic congestion occurs, delaying the movement of workers and the smooth trade of finished products (Gross and Ouyang 2021). Lacking free space for the natural expansion of production units, environmental pollution, and generally unfavorable living conditions for resident populations constrain further settlement growth (Kuang et al. 2020).

In order to deal with this unfavorable context, middle- and high-income households move to suburban locations with high environmental quality and favorable living conditions, giving room to the second stage of the SCT, namely, 'suburbanization' (Yang and Zhao 2022). Free-standing businesses follow such tendency, especially service businesses, since their executives (or customers) start experiencing a suburban life (Salvati and Sateriano 2015). In other words, they move to a better environment, ensuring improved working conditions and business prestige (Baker et al. 2000). The intrinsic movement of households, businesses, and workers to suburban locations leads to land saturation, worse traffic issues, environmental depletion, and the complete disappearance of traditional agricultural activities along the fringe (Sun and Zhang 2021). On the other hand, households and businesses have left a significant part of core cities almost empty. In the longterm, this development path has two implications, namely, (i) the latent shrinkage of economic activities downtown and (ii) the occupation of abandoned (or free) spaces by illegal activities and social (or ethnic) groups in consolidated (dense) settlements (Chen and Chi 2022). These effects often result in a sort of 'ghettoization' of metropolitan centers (Rontos et al. 2016). 'Suburbanization' is completed with the appearance of unfavorable conditions in saturated suburbs and the movement of households to new (satellite) cities or new settlements with a high-quality natural environment and more ideal living conditions (Antonoglou and Rontos 2023a).

Satellite cities thus become a key dimension of spatial planning, representing the natural evolution of modern lifestyles and satisfying the needs of a continuously expanding population into even larger metropolitan regions. Satellite cities share key functions with traditional centers, while remaining partially independent (economically and socially) from them, having, at the same time, their own urbanized area and absorbing part of the growth of surrounding cities, as a result ofa deteriorated quality of life therein. As the population of satellite cities increases, new settlements at an even greater distance from central locations can be observed, strengthening their role in industry, job markets, and local governance (Evans and Evans 2007). This path is recognized as the third stage of the SCT, namely, 'disurbanization'.

The theory predicts a fourth stage ('reurbanization'), where urban centers (namely, the core cities) experience a slowdown in population decline, and 'ghettoization' phenomena become less intense (Lever 1993). The possibility of improving housing conditions downtown, where old buildings are demolished and those in better condition are rebuilt, is an important factor in this development path. Consequently, central locations have a new wave of population growth, with declining trends in suburban places. In some cases, this development reflects the reverse movement of households from suburbs to city centers.

Responding effectively to the spatial cycle of cities, urban policies should be formulated accordingly and adjusted dynamically. For instance, decentralization policies can prove ineffective in metropolitan areas undergoing 'disurbanization'. At the same time, urban regeneration policies should take account of the specific stage of the spatial cycle, and development actions should be 'pro-cyclically' adapted to demographic dynamics over large metropolitan regions. The evolution of urban and regional centers, according to the SCT (Kawashima 1986), is presented in Figure 1. Changing population in the core city and in the surrounding suburbs is illustrated, respectively, on the horizontal and vertical axes. In this graph, the cycle is illustrated with sequential waves (from the beginning to the end of the circular development path), considering the stages described above and the intermediate phases inbetween.

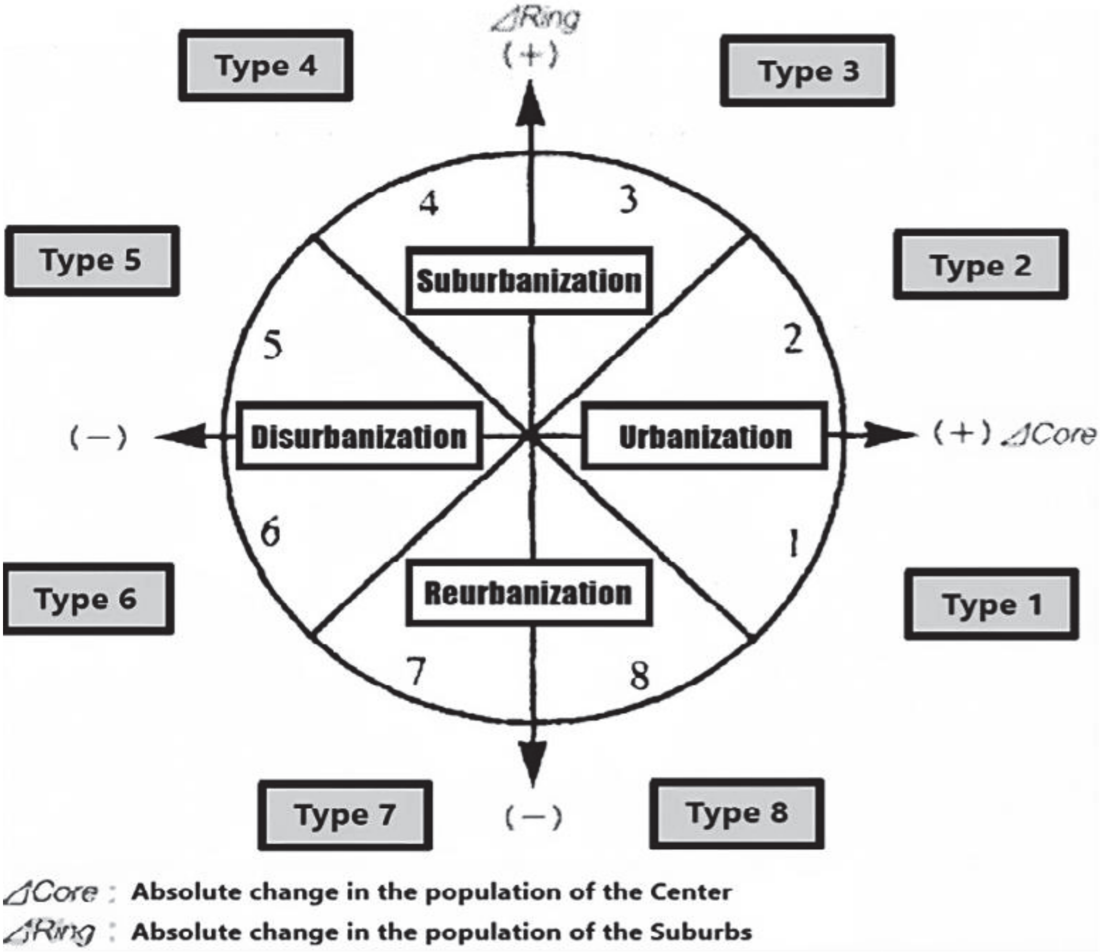

Figure 1. A graphical illustration of the four stages of the Spatial Cycle, and the intermediate development waves (1 to 8), in a given metropolitan region. Source: authors' adaptation of Kawashima (1986) drawings.

- 'Urbanization' appears when the Cartesian Product of the above two quantities is positive ('Type 1'), namely, when urban population increases with a contemporary decline of suburban population (the so-called, 'absolute urbanization'). In the Type 2 development class, the populations of both areas increase, with a slowing growth rate involving urban settlements and an accelerating rate observed in suburban locations (the so-called 'relative urbanization').

- 'Suburbanization' corresponds to a Type 3 development (the so-called 'relative suburbanization'), where urban population increases at a slower rate and suburban population increases at an accelerated rate; meanwhile, Type 4 development implies a population decreasing in central locations with uneven suburban growth (the so-called 'absolute suburbanization').
- 'Disurbanization' occurs when the Cartesian Product of population changes is classified as Type 5 development (the so-called 'absolute disurbanization'); central settlements continue experiencing an even more accelerated decline, while the suburbs display a slowdown in population growth. Type 6 development (the so-called 'relative disurbanization') sees the centers continuing the sharp loss of resident population, with decreasing populations also in the suburbs, for the first time since the beginning of the cycle.
- The wave displaying a moderate regrowth of central locations is detailed in Type 7 development (the so-called 'relative re-urbanization'), with core cities showing a decelerated population decline and the suburbs evidencing an accelerated decline; Type 8 development (the so-called 'absolute re-urbanization'), implies a net increase in central populations, and suburbs display a net slowdown of population decline.

Taken together, regional population (core city and suburbs) increases during 'urbanization' and 'suburbanization', while decreasing in favor of outer satellite settlements during the subsequent stages of 'disurbanization' and 'reurbanization' (Vining and Kontuly 1978).

With the framework of the SCT, Noordstrom (1981) investigated local-scale urban growth patterns and processes extensively, evidencing demographic changes vis-à-vis sequential developmental stages of a given city. Accordingto the SCT, population, settlements, and economic activities are assumed to be significantly influenced by a mix of regional development and socio-cultural and politic/institutional changes at the local scale (Kontuly and Geyer 2003). Noordstrom also argued that when a society develops, all the activities that affect employment—and, consequently, the spatial structure of populations and settlements—undergo (more or less intense) changes articulated into various stages. Consequently, the effect of environmental conditions and local policies, which constitute the basic drivers of population structure and dynamics in modern societies, can be delineated and interpreted in a broader perspective of regional growth. The impact of policy and planning is also emphasized in light of the SCT (Korcelli 1986).

Based on this assumption, this study implements a spatially explicit interpretation of metropolitan growth and decline over a sufficiently long time interval, considering population change at the local level as an honest measure of regional development paths, taking account of the 'intensity' and 'spatial direction' dimensions jointly (Geyer and Kontuly 1993). We specifically tested the assumptions of the SCT delineated above, moving from a regional to a local approach that considers together population dynamics at the core, the suburban and satellite locations (Kontuly 1992). Informed by a seminal study of Noordstrom (1981), this local-scale approach incorporates theoretical and empirical evidence from a relatively broad literature of urban geography and applied economics since the late 1980s.

At the local level, we assume urban structure to be basically depending on (i) land, namely, the available space per inhabitant, and (ii) population size, namely, the total number of inhabitants or, better, population density. With this perspective in mind, the empirical analysis of urban development may benefit from the comparative scrutiny of population change over time and space, as available at an appropriate geographical unit from general censuses (Aplerovich 1983; Schwizer 1985; Kawashima 1986). Regardless of the variable's choice (e.g., Kontuly and Tammaru 2006) or the level of analysis of urban development, a systematic verification of the SCT is achieved by dividing the urban area into distance zones from a central point of the core city and grouping the population residing in the municipalities (or settlements) falling within these zones, in line with mainstream empirical studies (e.g., Morelli et al. 2014).

The following analysis's step consists in an explicit examination of population growth (and decline) in aggregated districts within a given time period. This empirical test is grounded on a seminal application by Noordstrom (1981), who divided the city of Gothenburg into communities, grouping them based on their distance from downtown and studying the evolution of population density for these communities over a relatively long-time interval, encompassing 60 years. In the same line of thinking, Kawashima (1986), in a study of the development stages in the Tokyo metropolitan area, classified the city into urban and rural zones—according to their distance from downtown—and analyzed population changes in these zones during nearly 30 years. Stemming from the empirical conclusions of the above-mentioned studies (Vining and Kontuly 1977), our work is aimed at demonstrating how the highest value of the target variable (population density, in the present case) is observed first at small distances from a central point of the core city and, progressively on subsequent times, moving farther away from downtown.

Taken as a purely mono-centric model of regional growth (as extensively documented in earlier studies), we adopted metropolitan Athens in Central Greece as an appropriate case study when investigating and predicting the inter-urban movement of the resident population over time. Besides Istanbul, Athens—the Greek capital city—is one of the largest and economically powerful centers in the north-eastern Mediterranean arc (Egidi et al. 2020), having a very complex development path driven by a kaleidoscopic mix of internal factors (demographic dynamics, planning constraints, social forces) and external shocks, which include—but are not limited to—the Turkish–Greek war in the early 1920s, World War II and the consequent civil war in Greece, the intense rural exodus of the 1960s causing internal migration mainly toward Athens, the accession to the European Union in the 1980s, the Olympic decade of the 1990s, the economic decline of the late 2000s, and, finally, the COVID-19 pandemic. Together with census data, our study—likely for the first time in the literature—offers a reasonable perspective of future development paths based on population projections interpreted in light ofthe Spatial Cycle Theory, taken as an operational contribution to spatial planning and local development policies (Vinci et al. 2022). Reconnecting past, present, and future population dynamics in a local-scale perspective typical of urban analysis represents the original contribution of this study to regional science.

2. Methodology

This study investigates the sequential stages of the spatial cycle in metropolitan Athens (Central Greece) in line with the original formulation by Klaassen et al. (1981) and the extension by Kawashima (1986). The study area was extensively described by Salvati et al. (2018), Zambon and Salvati (2019), Zambon et al. (2019), and Salvati (2023). Metropolitan Athens was divided into a few concentric zones at aincreasing distance from downtown (0 to 6 km, 6 to 12 km, 12 to 18 km, 18 to 42 km, 42 to 60 km), considering Constitution Square (Plateia Syntagmatos) as the city center. In cases where a given municipality belonged to two neighboring zones, it was classified to be within the zone where most of its surface area exists.

The evolution over time of the resident population was thus investigated separately in these zones by aggregating municipal data derived from decadal censuses, which allowed for a thorough clarification of spatial cycle timing (Cecchini et al. 2019). Following earlier studies (Rontos and Papadaskalopoulos 1994; Rontos et al. 2006; Morelli et al. 2014; Ciaschini et al. 2023), the intra-metropolitan population net balance (growth vs. decline) was calculated on a decadal time interval during the period 1951–2021. Additionally, the total population at the municipal level was projected for the years 2031, 2041, and 2051 using the exponential rate of population growth during the most recent inter-census period (namely, 2011–2021). The method used assumes that population growth is not constant, reflecting an exponential function of time (Siampos 1993). This approach is taken to be fully appropriate for population forecasts according to demographic methodologies (e.g., Papadakis and Tsimpos 2004). More precisely, the econometric specification used is as follows:

$$P_n = (1 + r)^{n} \cdot P_{n-1}$$

where n is the time period between $n - 1$ and n, r is the mean population growth rate between $n - 1$ and n, P_n is the population to be projected at time n, P_{n-1} is the population at time $n - 1$; and the term (1 + r) is recalled as the growth multiplier, or common ratio.

Together with metropolitan Athens, the study area included the satellite cities of Thebes (Thiva), Halkida (Chalkida), and Corinth (Korinthos) as a novel contribution to the empirical verification of the SCT in Central Greece. Based on the empirical observation of census data and demographic predictions, this study covers a relatively long time period encompassing exactly one century (1951–2051), intended as a meaningful tool for regional policy and spatial planning in Greece, with implications for similar countries in Europe and outside the old continent. Metropolitan Athens was initially partitioned into sub-areas according to the most recent statistical and administrative system enforced in the country, namely, the wider area of Athens's conurbation (including the municipality of Athens, Piraeus, and the surrounding districts) and the rest of the administrative region of Attica. This spatial division was considered basically appropriate to ensure a full compatibility of population trends over the selected geographical units from 1951 to the present time. Microsoft Excel 2016 spreadsheets, SPSS v.26 statistical package, and GeoDa 1.22.0.4.9 geographical tools were used to process the empirical results of this study.

3. Results

Athens's spatial cycle is illustrated in Figure 2 based on long-term population dynamics. As described in the methodological section, the *X*-axis and the *Y*-axis of the graph, respectively, measure the absolute change in urban and suburban populations over the studied decades. The points representing the following decades (1951–1961, 1961–1971, 1971–1981, 1981–1991, and 1991–2001) are classified within the third quadrant of the spatial cycle graph, corresponding to a Type 3 development path. This suggests that suburbs around Athens developed continuously between 1951 and 2001. Coherent with a Type 3 development path ('relative suburbanization'), both urban and suburban populations increased. During the subsequent decades (2001–2011 and 2011–2021), the Cartesian Product of the population change in the two regions moved to the fourth class of the spatial cycle. This path reflects a Type 4 development ('absolute suburbanization'), with the downtown population decreasing while the suburban population increasing at an accelerated rate. As a whole (core *plus* suburbs), the region continued growing in terms of population. Finally, based on population forecasts for the decades 2021–2031, 2031–2041, and 2041–2051, the Cartesian Product of the changes marginally returned to the third side of the spatial cycle graph. These results suggest how metropolitan Athens could experience a new wave of Type 3 development in the next years, possibly mixing 'relative suburbanization' with a moderate (demographic) recovery of core cities.

The spatial direction and intensity of suburban development across geographical areas result from the empirical data analyzed in Table 1. Downtown Athens and Piraeus (namely, the city with the largest harbor in Greece) were constantly reducing their share in the total population of the whole area. Their demographic role halved between 1951 (36.3%) and 2021 (18.9%) for Athens, and reduced even three times for Piraeus in the same time interval, from 12.6% to 4.9%. At the same time, Western Attica suburbs showed a significant increase in their population share, which reflects a faster demographic increase in respect of the core city, with the highest rate (17.1%) observed in 1971, the year when the maximum urban concentration was observed (Salvati 2023).

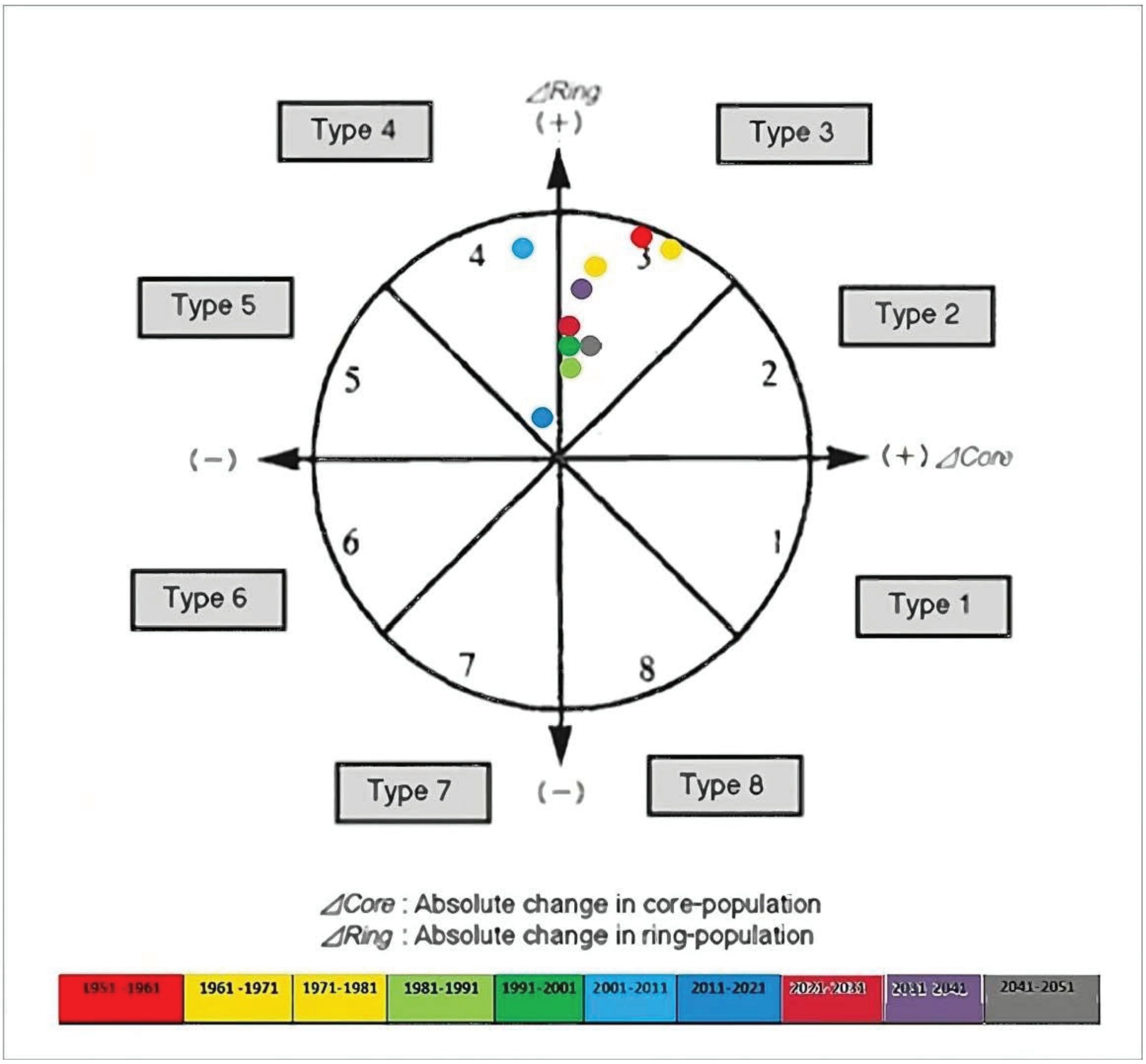

Figure 2. Circular diagram of the spatial cycle in metropolitan Athens, 1951–2051. Source: authors' elaboration on population census data (ELSTAT).

Eastern suburbs' population weight in total area increased as well from 5.4% (1951) to 14.9% (2021), highlighting a rapid—and almost continuous—development process. The most remote areas of both Eastern and Western Attica (the so-called 'rest of Attica') also increased their demographic weight since 1991 or 2001. As a novel issue, the satellite cities of Thebes, Halkida, and Corinth (situated outside metropolitan Athens) showed a relative stability in their demographic weight following a moderate stagnation (1961–1991). In other words, the contribution of such satellite cities to population deconcentration in metropolitan Athens was modest or null, likely because of restricted accessibility and less effective transportation services, both public and private (Rontos and Papadaskalopoulos 1994). This may be explained by the insufficient industrialization of satellite cities and their modest tourism specialization, despite the presence of important archeological sites. A systematic classification of the study area by concentric zone using linear distance from downtown Athens allows for delineating local development paths against the dominant regional growth pattern (Figure 3).

Table 1. Percent share of resident population in total population by administrative unit (1951–2021).

	ADMINISTRATIVE UNITS	YEAR							
		1951	**1961**	**1971**	**1981**	**1991**	**2001**	**2011**	**2021**
Capital region	City of Athens (downtown)	36.3	30.7	31.1	26.6	21.5	22.5	19.3	18.9
	Department of Athens, except Athens [1]	8.6	10.0	10.5	11.5	10.9	11.2	10.6	10.5
	City of Piraeus (downtown)	12.6	9.3	6.7	5.9	5.0	5.2	4.8	4.9
	Piraeus Department, except Piraeus [2]	16.8	18.1	17.8	19.5	20.0	19.3	19.0	18.9
	Western Attica District Department [3]	9.5	15.4	17.1	16.9	16.7	14.3	14.3	14.0
	Eastern Attica Department of Transport [4]	5.4	7.1	7.8	10.3	12.6	12.1	14.5	14.9
Rest of Attica Prefect.	Department of Piraeus [5]	1.3	1.1	0.9	0.8	1.1	2.0	2.2	2.0
	Department of Eastern Attica [6]	3.3	3.0	3.0	3.4	6.2	5.9	7.1	7.3
	Department of Western Attica [7]	2.4	2.9	2.6	2.9	2.9	4.3	4.7	4.9
External cities	Thiva, Chalkida, Corinth	3.7	2.9	2.6	2.9	2.9	3.1	3.5	3.6
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: authors' elaboration on population census data (ELSTAT). Notes: [1] Municipalities of Byronos, Galatsiou, Dafni, Zografou, Iliopolis, Kaisariani, Nea Philadelphia, Nea Chalkidonos, Tavrosand Ymittos; [2] Municipalities of Agios Dimitrios, Agios Ioannis Rentis, Alimos, Argyroupolis, Voula, Vouliagmeni, Glyfada, Drapetsona, Elliniko, Kallithea, Keratsini, Moschato, Nea Smyrni, Nicea, PalaioFaliro, Perama, and Vari, except Piraeus; [3] Municipalities of Agia Varvara, Agios Anargyro, Aigaleo, Kamatero, Korydallos, Neo Liosion, Peristeri, Petroupoles, and Chaidari; [4] Municipalities of Agia Paraskevi, Amarousi, Vrilissi, Heraklion, Kifissia, Melissi, Metamorfosis, Nea Erythraia, Nea Ionia, Neo Psychiko, Papago, Pefki, Philothei, Chalandrio, Cholargo, Psychiko, and GerakaandCommunities of Ekali, Lykovrisi, Nea Penteli, and Penteli; [5] Municipalities of Aegina, Salamina, and Hydra (urban and semi-urban areas of over 5000 inhabitants); [6] Municipalities of Avlonos, Acharnon, Keratea, Kropia, Lavreotiki, Marathon, Markopoulou Mesogaia, Nea Makri, Paiania, Pallini, and Spaton—Loutsa and Communities of Agios Stefanos, Artemis (Loutsa), Glykon Neron, and Oropou (urban areas and semi-urban areas over 5000 resident); [7] Municipalities of Aspropyrgos, Vilia, Elefsinos, Erythron, Mandras, Megareon, Ano Liosion, Zephyrio, and Fylis and Community of Nea Peramos (urban areas and semi-urban areas with more than 5000 inhabitants).

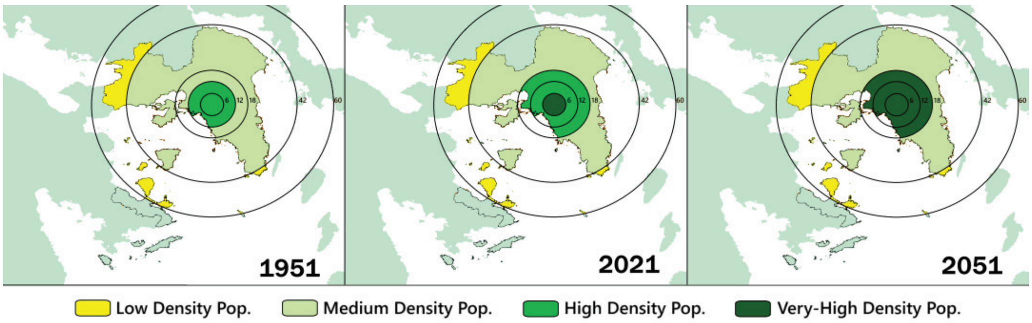

Figure 3. Population density in metropolitan Athens (1951, 2021, 2051) by concentric belts reflecting the linear distance from Plateia Syntagmatos, downtown Athens (km). Source: authors' elaboration on population census data (ELSTAT).

Table 2 shows the evolution of the total population by concentric zone as defined above. The empirical results of this analysis delineate some important conclusions on the evolution of Athens's population.

Additionally, Table 3 displays the rate of population change by concentric zone. A spatial shift inthe highest population change rate was initially observed from central zones to peripheral ones. In the zone 0–6 km away from downtown Athens, the highest rate of population change occurred during 1961–1971 (36%). Interestingly, the highest rate of population change occurred one decade earlier (1951–1961) in the zone 6–12 km away (35%). Conversely, it was observed only during 2001–2011 (57%) for the concentric zone 12–18 km away from downtown. The highest value of change observed in metropolitan Athens's population during 1961–1971 could be justified by intense internal migrations from rural

Greece. However, considering the relative differences instead of absolute differences in a comparative perspective, it was noted how the second belt (6–12 km) grew fastest in the period 1951–1961, while the third belt (12–18 km) grew fastest in the subsequent period 1961–1971 (41%), totalizing a very high demographic increase also during 1971–1981 (40%), 1981–1991 (33%), 1991–2001 (30%), and 2001–2011 (57%). Altogether, these results may confirm the assumptions of Kawashima's SCT.

Table 2. Population of metropolitan Athens by concentric zone (km from downtown Athens) for the time period 1951–2051; 'Total' refers to metropolitan Athens.

Zone	Municipality	1951	1961	1971	1981	1991	2001	2011	2021	2031	2041	2051
0 to 6	20	850,435	1,123,027	1,595,901	1,817,059	1,681,767	1,691,532	1,524,167	1,495,483	1,536,981	1,647,730	1,738,579
6 to 12	30	469,713	664,044	870,866	1,081,506	1,169,646	1,263,788	1,387,862	1,383,114	1,520,668	1,711,178	1,877,768
12 to 18	20	77,784	108,838	162,675	241,589	335,012	450,349	704,932	728,439	941.005	1,339,063	1,662,083
18 to 42	46	97,993	113,369	131,619	178,288	244,250	312,791	203.405	199,636	256,810	353,416	434,902
42 to 60	1	4286	4170	3879	4973	6017	5933	8068	7392	10,578	17,000	18,904
Total	117	1,500,211	2,013,448	2,764,940	3,323,415	3,436,692	3,724,393	3,828,434	3,814,064	3,961,586	4,044,785	4,123,847

Source: authors' elaboration on population census data (ELSTAT).

Table 3. Rate of population change by concentric belt (km), 1951–2051.The highest rate for each belt is marked in bold. 'Total' refers to metropolitan Athens.

Concentric Belt	1951–1961	1961–1971	1971–1981	1981–1991	1991–2001	2001–2011	2011–2021	2021–2031	2031–2041	2041–2051
0 to 6	28	**36**	13	−8	1	−10	−2	3	7	6
6 to 12	**35**	27	22	8	8	10	0	10	13	10
12 to 18	34	41	40	33	30	**57**	3	29	42	24
18 to 42	15	15	31	**32**	25	−35	−2	29	38	23
42 to 60	−3	−7	25	19	−1	**36**	−8	43	61	11
Total	30	**32**	19	3	8	3	0	4	2	2

Source: authors' elaboration on population census data (ELSTAT).

Nevertheless, it should be noted that the outermost belts of 18 to 42 km and 42 to 60 km show a notable population increase only in the time interval 1981–2011. During the decade 1981–1991, the largest increase in population concentrated in peripheral belts, especially in the 18–42 km zone, which almost equaled the expansion of the previous zone (32%), while it 'tookoff' between 2001 and 2011 in the 42–60 km concentric zone. A possibly unexpected development path was also observed in the 42–60 km distance belt between 2001 and 2011, against a negative population growth in the previous decade (−1%). Population stabilized in the subsequent decade 2011–2021, likely because of economic crisis, the COVID-19 pandemic, geo-political tensions, and inflation rise. However, the intense decrease in the resident population of the 18–42 km belt between 2001 and 2011 (−35%) was hardly explained bythe above-mentioned reasons. Althoughconsidered with caution, population forecasts indicate a significant growth of the outermost zones, likely stabilizing after 2041.

4. Discussion

Long-term development stages of metropolitan Athens were investigated in this study according with the Spatial Cycle Theory (Klaassen et al. 1981; van de Berg et al. 1982; Kawashima 1986). The main conclusion of this empirical application is that the area experienced a prolonged suburbanization stage, initially assuming the development type of 'relative suburbanization'—whichwas maintained, almost continuously—during the second half of the 20th century, with the downtown population growth slowing down and an accelerating growth of the suburban population. In the first two decades of the 21st century, thedevelopment type of 'absolute suburbanization' emerged and consolidated, with a decreasing downtown population and a moderate increase inthe suburban population. Population forecasts finally indicate a new shift toward 'relative suburbanization', reflecting a moderate recovery of downtown Athens. The demographic and economic recovery of inner Athens can be justified byintrinsic changes in the structure of regional and local productions and activities, mainly leveraged by technological improvement, better accessibility, the growth of high-income sectors (such as finance, research and development, and real estate), and tourism concentration (Rontos and Vavouras 2013).

Information technology, urban sustainability, and new lifestyles (e.g., digital nomads, long-term rental of Airbnb-style housing, changes over time in energy and transport costs) may bring economic activity back to city centers and the surrounding areas. The concentration of foreign immigrants and refugees downtown in Athens is an additional engine of such development paths, considering that, in 2021, the Attica region hosted 45% of-thetotal foreign population in Greece. Migrants settled in downtown Athens because of cheaper housing rents, public transportation, a relatively large opportunity for collective accommodation, social benefits from state agencies or municipalities (e.g., social housing, state pharmacy, public and free medical doctors), and concentration of nationals, forming well-known 'ghettos'—in the districts of Omonia, Metaxourgiou, Pedion ton Areos, and Mavromateon).

According to Mäding (2004), negative externalities have an impact on properties and jeopardize social goals. In the case ofAthens, this can be briefly explained as follows: middle-class families leave inner cities and look for suburban districts with single-family houses or more spacious apartments, while minority or even delinquent groups are concentrated in the city center (e.g., 'ghettoization');meanwhile, population increase, changes in household structure, and higher demand for large housing, resulting from income growth, further expand the supply of more settlements in suburbs (Rontos and Roumeliotou 2009). The spatial expansion of residential areas leads to an ever-increasing demand for built-up space, with important ecological consequences (Rontos et al. 2014). Despite a moderate demographic recovery of inner cities forecasted for the coming decades, the main feature emerging from the analysis is a persistent suburban dynamic over a relatively longtime interval. The results of recent censuses may confirm such assumptions, although one would expect a transition to the next stage of the spatial cycle due to the demographic saturation of suburbs. On the basis of such evidence, the Spatial Cycle Theory predicts the emergence of a third stage ('disurbanization'), with the development of progressively remote settlements. As Noordstrom (1981) noted, the vertical profile of Athens's suburbs, with the continuous replacement of single-family houses into multi-story buildings, may document the continuous absorption of an even expanding population. Although the urbanization trend continues at a weaker pace, suburbs continue growing in both population and activities.

Since the early 1990s, the entry of a large number of immigrants into Greece has significantly affected the regional distribution of the total population in the country, especially in metropolitan Athens. In 2001, 324,167 immigrants out of 413,201 (78.5%) settled in urban areas, and 60.6% of them (196,392 immigrants) were concentrated in metropolitan Athens. The same data source reveals that 2764 (94.6%) immigrants who declared themselves as refugees out of 2920 individuals settled in urban areas. The 2011 population census gave the same picture. Of the 329,556 foreigners who settled in Greece in the period 2006–2011, 244,410 (74.2%) were concentrated in urban areas. The redistribution of regional population in response to migration flows was evident from the official statistics concerning Greece. In the last decade, apart from a short break concomitant with the great recession, and especially after 2015, Greece again experienced a significant influx of refugees, mainly through Eastern Aegean islands (Samos, Lesvos) and the Evros region (Turkish boundaries). A significant number of refugees moved to metropolitan Athens, either individually or as organized by the State and Non-Governmental Organizations. A significant part of all the above movements was directed to downtown Athens, but another non-negligible portion of movements involved the surrounding suburbs, depowering the 'ever-green' suburbanization stage.

The concentration of public and private sector services in Athens (Ministries, Deputy Ministries, Headquarters of the Armed Forces, Security Forces, Administrative Services, Hospitals, Banks) operated competitively with the housing needs of a slightly growing population and contributed to additional movements of residents to the suburbs, in turn eliminating late suburbanization. The result of 'suburbanization' (either absolute or relative) is the persistence of external negative economies (e.g., traffic jams). The lack of space for the expansion of business facilities (especially extensive activities such as storage or distribution of products) appears together with air pollution and unfavorable living conditions (Antonoglou and Rontos 2021).

Moving toward a sub-regional perspective, an intense population growth occurred in both eastern and southern suburbs near the core city, where middle and upper classes settled. However, intense growth was also recorded in less expensive western suburbs, where the working class has systematically settled since the 1950s. Since the early 1990s, the most distant suburbs of Eastern and Western Attica started growing and displayed some trends toward remote development. The satellite cities of Thebes, Corinth, and Halkida, at a distance between 70 and 80 km from Athens, do not seem to attract intense flows from the Greek capital city.

A systematic implementation of the spatial cycle carried out in this study suggested some future directions of empirical research in urban studies and applied economics. A first issue is with regardtothe partial lack of geographic comparability in population statistics before and after the First World War in Greece because of intense administrative changes in municipalities and local communities. In such times, extraordinary events—such as the influx of a number of refugees from Asia Minor in 1922 and from rural areas following the civil war of the late 1940s—merit a specific investigation in the context of the SCT, but the available data provide only an aggregate picture that cannot satisfy the information demand of spatially explicit techniques. This lack limits the historical verification of the SCT over two centuries, namely, from the foundation of the modern Greek state around 1830, when Athens settled only 30 thousand inhabitants, after centuries of abandonment and peripheral development under the Turkish domination.

Testing the SCT from the 'foundation' of a city is a particularly meaningful quasi-experiment. AlthoughAthens was one of the most ancient cities in the world, the secular Turkish domination created a breakdown between the historical city dynamics and the modern ones, with this study clearly reflecting only the latter dynamics. The inherent comparability in population data was addressed with separate calculations in the context of this study, as the radical administrative changes that came to Greece with the Kapodistrias and Kallikratis Plan made the aggregate data released within the most recent population censuses as only partly comparable over time and space. Given the recognized usefulness of a spatially explicit analysis, the competent Statistical Authority (ELSTAT, in our case) should operationally address this issue (e.g., Robinson et al. 1993).

Finally, as a continuation of this study, further research could be carried out based on a refined investigation of sequential waves of growth and decline (e.g., Newsham and Rowe 2023). For instance, the results of a multi-way factor analysis taking into account variables such as inflow/outflow of immigrants, births, deaths, health status, life expectancy, and quality-weighted life years, may shed further light on the future development of metropolitan Athens and, for generalization, of many other European cities and regions. The use of Moran's coefficient or other indexes of spatial autocorrelation may refine such kind of analysis. Statistical analysis may specifically shed light on (mostly unresolved) critical issues to be answered, e.g., whether (and when) latent downtown redevelopment trends will lead to a smooth transition toward 're-urbanization' or to a less predictable evolution toward 'disurbanization'.

In this perspective, the evolution of the spatial cycle in metropolitan regions revealed to be particularly important when formulating regional policy, since urban centers have their own dynamics and evolve even in conditions of non-intervention. Despite partial and possibly preliminary, the results of our study indirectly suggest how decentralization policies are partly ineffective in both urban containment and local development leverage, especially during of the third stage of the spatial cycle ('disurbanization'). Similarly, the fourth stage of the spatial cycle ('reurbanization') may impact the effectiveness of urban regeneration policies. Assuming a long-term development path reflecting intense urbanization, saturation of vacant land, and subsequent decentralization pulses, departures from the traditional assumptions of the SCT contribute to the informed formulation of urban planning strategies and specific regional policy measures.

5. Conclusions

Analysis of demographic dynamics between urban and rural areas possibly reflecting the related intra-urban spatial relations (from both social and economic perspectives) is a traditional issue in regional science, affecting the geographical distribution and balance of economic power within countries. Based on the results of the empirical analysis, the study area first experienced a persistent stage of 'relative suburbanization' and, subsequently, an 'absolute suburbanization' stage. Population forecasts delineate a tendency toward relative suburbanization with a modest recovery of the resident population downtown. The demographic role of satellite cities increased moderately, highlighting latent trends of 'disurbanization'. Based on the predictions of the spatial cycle theory, our study constitutes an informative tool for planning the country's regional development and urban policy in a comparative fashion.

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References

Angel, Shlomo, Parent Jason, Blei Alexander, Potere David, and Civco Daniel. 2011. The Dimensions of Global Urban Expansion: Estimates and Projections for all Countries, 2000—2050. *Progress in Planning* 75: 53–107. [CrossRef]

Antonoglou, Dimitrios, and Kostas Rontos. 2021. Regional Inequalities in the healthcare delivery system in Greece. In *International Electronic Periodical Edition of the Journal Policies and Social Sciences*. Patras: Georgogiannis Pantelis, Issue 14, ISSN 2459-2862.

Antonoglou, Dimitrios, and Kostas Rontos. 2023a. Measurement of the geographical distribution of health services in Greece: A quantitative analysis. In *Collective Volume A titledSocial Sciences Today: Dilemmas and Perspectives Beyond the Crisis*. Edited by Nikos Nagopoulos, Nasia Chourmouziadi, Dimitris Paraskevopoulos, Vasiliki Katsamaka and Themelio Editions. Mitilini: School of Social Sciences, University of the Aegean. ISBN 978-618-82208-9-8.

Antonoglou, Dimitrios, and Kostas Rontos. 2023b. Problems and perspectives of the less developed regions in the modern socio-economic environment. In *Greece, Europe & the World-Studies on European and International Politics*. Edited by Sotiris Dalis. Mitilini: Department of Mediterranean Studies of the Faculty of Humanities of the University of the Aegean. Papazisi Publications, Issue 19.

Aplerovich, Gershon. 1983. An Empirical Study of Population, Density Gradients and their Determinants. *Journal of Regional Science* 23: 529–40.

Bai, Xuemei, Jing Chen, and Peijun Shi. 2012. Landscape urbanization and economic growth in China: Positive feedbacks and sustainability dilemmas. *Environmental Science & Technology* 46: 132–39.

Baker, Emma, Neil T. Coffee, and Graeme Hugo. 2000. *Suburbanization vs. Reurbanization: Population Distribution Changes in Australian Cities*. Canberra: Department of the Environment and Heritage.

Black, Duncan, and Vernon Henderson. 2003. Urban evolution in the USA. *Journal of Economic Geography* 3: 343–72. [CrossRef]

Cecchini, Massimo, Ilaria Zambon, Antonella Pontrandolfi, Rosario Turco, Andrea Colantoni, Anastasios Mavrakis, and Luca Salvati. 2019. Urban sprawl and the 'olive' landscape: Sustainable land management for 'crisis' cities. *GeoJournal* 84: 237–55. [CrossRef]

Champion, Antony. 1989. *Counter Urbanization: The Changing Pace and Nature of Population Decentralization*. London: Arnold.

Champion, Antony. 2000. Urbanization, suburbanization, counter urbanization and reurbanization. In *Handbook of Urban Studies*. Edited by R. Paddison and W. Lever. London: Arnold.

Chen, Mingxing, Hua Zhang, Weidong Liu, and Wenzhong Zhang. 2014. The global pattern of urbanization and economic growth: Evidence from the last three decades. *PLoS ONE* 9: e103799. [CrossRef] [PubMed]
Chen, Wanxu, and Guangqing Chi. 2022. Urbanization and ecosystem services: The multi-scale spatial spillover effects and spatial variations. *Land Use Policy* 114: 105964. [CrossRef]
Ciaschini, Clio, Adele Sateriano, Kostas Rontos, Bogdana Nosova, and Luca Salvati. 2023. Toward a Mediterranean Urban Crisis? In *Urban Crises: Social and Economic Implications for Southern Europe*. Edited by Adele Sateriano. New York: NOVA publisher.
Cross, D. 1990. *Counter urbanization in England and Wales*. Aldershot: Ashgate.
Egidi, Gianluca, Luca Salvati, and Sabato Vinci. 2020. The long way to tipperary: City size and worldwide urban population trends, 1950–2030. *Sustainable Cities and Society* 60: 102148. [CrossRef]
Evans, D., and O. W. Evans. 2007. *The Complete Real Estate Encyclopedia*. Cambridge: Mc Graw Hill Professional.
Fielding, A. 1982. Counter urbanization in Western Europe. *Progress in Planning* 17: 1–52. [CrossRef]
Findley, Sally E. 1993. The third world city: Development policy and issues. In *Third world Cities*. Edited by J. Kasarda and A. Parnel. London: Arnold.
Geyer, Hermanus S., and Thomas Kontuly. 1993. A theoretical foundation for the concept of differential urbanization. *International Regional Science Review* 15: 157–77. [CrossRef]
Gross, James, and Yu Ouyang. 2021. Types of urbanization and economic growth. *International Journal of Urban Sciences* 25: 71–85. [CrossRef]
Haase, Dagmar, Nadja Kabisch, and Annegret Haase. 2013. Endless urban growth? On the mismatch of population, household and urban land area growth and its effects on the urban debate. *PLoS ONE* 8: e66531. [CrossRef] [PubMed]
Henderson, Vernon. 2003a. The urbanization process and economic growth: The so-what question. *Journal of Economic Growth* 8: 47–71. [CrossRef]
Henderson, Vernon. 2003b. Urbanization and economic development. *Annals of Economics and Finance* 4: 275–342.
Ji, Yunyang, Xiaoxin Guo, Shihu Zhong, and Lina Wu. 2020. Land financialization, uncoordinated development of population urbanization and land urbanization, and economic growth: Evidence from China. *Land* 9: 481. [CrossRef]
Kawashima, Toshiki. 1986. Spatial cycle hypothesis and Roxy index method: Implications of the 1985 population census figures for the stage of suburbanization of Tokyo Metropolitan area. Paper presented at the RSA Twenty Sixth European Congress, Krakow, Poland, August 26–29.
Klaassen, Leo H. 1981. *Transport and Re-Urbanization*. Hants: Gower Publishing Company.
Klaassen, Leo H., Willem Molle, and Jean Paelinck. 1981. Dynamics of Urban Development. In *Proceedings of an International Conference Held on the Occasion of the 50th Anniversary of the Netherlands Economic Institute in Rotterdam, September 4, 1979*. Ann Arbor: University of Michigan.
Kontuly, Thomas. 1992. National-, regional-and urban-scale population deconcentration in West Germany. *Landscape and Urban Planning* 22: 219–28. [CrossRef] [PubMed]
Kontuly, Thomas, and Hermanus S. Geyer. 2003. Lessons learned from testing the differential urbanisation model. *TijdschriftvoorEconomischeenSocialeGeografie* 94: 124–28. [CrossRef]
Kontuly, Thomas, and Tiit Tammaru. 2006. Population subgroups responsible for new urbanization and suburbanization in Estonia. *European Urban and Regional Studies* 13: 319–36. [CrossRef]
Korcelli, Piotr. 1986. Growth rate fluctuations and alternative trajectories of future populations change: A case of Warsaw region. Paper presented at the RSA twenty Sixth European Congress, Krakow, Poland, August 26–29.
Kuang, Bing, Xinhai Lu, Jing Han, Xiangyu Fan, and Jian Zuo. 2020. How urbanization influence urban land consumption intensity: Evidence from China. *Habitat International* 100: 102103. [CrossRef]
Lever, William F. 1993. Reurbanization—The policy implications. *Urban Studies* 30: 267–84. [CrossRef]
Li, Xuecao, Yuyu Zhou, Mohamad Hejazi, Marshall Wise, Chris Vernon, Gokul Iyer, and Wei Chen. 2021. Global urban growth between 1870 and 2100 from integrated high resolution mapped data and urban dynamic modeling. *Communications Earth & Environment* 2: 201.
Mäding, H. 2004. *Suburbanization and Urban Development in Germany. Trends—Models—Strategies*. Berlin: DeutschesInstitut für Urbanistik.
Morelli, Vittorio G., Kostas Rontos, and Luca Salvati. 2014. Between Suburbanization and Reurbanization: Revisiting the Urban Life Cycle in the Mediterranean Compact City. *Urban Research and Practice* 7: 74–88. [CrossRef]
Newsham, Niall, and Francisco Rowe. 2023. Understanding trajectories of population decline across rural and urban Europe: A sequence analysis. *Population, Space and Place* 29: e2630. [CrossRef]
Niu, Bo, Dazhuan Ge, Rui Yan, Yingyi Ma, Dongqi Sun, Mengqiu Lu, and Yuqi Lu. 2021. The evolution of the interactive relationship between urbanization and land-use transition: A case study of the Yangtze River Delta. *Land* 10: 804. [CrossRef]
Noordstrom, Lars. 1981. Population changes in a functional regional system. *Economic Geography* 57: 183–98. [CrossRef]
Papadakis, M., and K. Tsimpos. 2004. *Demographic Analysis*. Athens: Stamoulis Publisher.
Robinson, J. Gregory, Bashir Ahmed, Prithwis Das Gupta, and Karen A. Woodrow. 1993. Estimation of population coverage in the 1990 United States Census based on demographic analysis. *Journal of the American Statistical Association* 88: 1061–71.
Rontos, Kostas, and Athanasios Papadaskalopoulos. 1994. The Approach of Spatial Cycle: The Case of the Athens Metropolitan Area 1951–1991. *Journal of Greek Official Statisticians* 30.

Rontos, Kostas, and Ioannis Vavouras. 2013. Socioeconomic and Political Development: Their Measurement and Connections. *Global Journal of Human Social Science* 13: 51–65.
Rontos, Kostas, and M. Roumeliotou. 2009. Social Trust in Local Communities and its Demographic, Socio-economic Predictors: The Case of Kalloni, Lesvos, Greece. *International Journal of Criminology and Sociological Theory* 2: 1.
Rontos, Kostas, Christos Mavroudis, and Theodore Georgiadis. 2006. Suburbanization: A Post World War II Phenomenon into the Athens Metropolitan Area, Greece" (paper number 939). Paper presented at the an R-session at the ERSA 2006 Congress, Volos, Greece, August 30–September 3.
Rontos, Kostas, Efstathios Grigoriadis, Adele Sateriano, Maria Syrmali, Ioannis Vavouras, and Luca Salvati. 2016. Lost in protest, found in segregation: Divided cities in the light of the 2015 "Οχι" referendum in Greece. *City, Culture and Society* 7: 139–48. [CrossRef]
Rontos, Kostas, Nikos Nagopoulos, and Flora Tsapala. 2014. Social elites and new media/information technologies: The digital divide. Paper presented at the Conference Media and Power, Panteion University, NKUA, ISA, InstitutFrancais, AISEF, Kallithea, Greece, January 22–23.
Salvati, Luca. 2023. A Long Way to Complexity: Nonlinear "Growth Stages" and Spatially Uncoordinated Settlement Expansion in a Compact City (Athens, Greece). *Geographical Analysis* 55: 280–99. [CrossRef]
Salvati, Luca, Agostino Ferrara, and Francesco Chelli. 2018. Long-term growth and metropolitan spatial structures: An analysis of factors influencing urban patch size under different economic cycles. *GeografiskTidsskrift—Danish Journal of Geography* 118: 56–71. [CrossRef]
Salvati, Luca, and Adele Sateriano. 2015. In-between coast and inland: A long-term assessment of demographic dynamics, agriculture and urban growth in Rome prefecture. *RendicontiLincei* 26: 605–14. [CrossRef]
Salvati, Luca, Maria Teresa Ciommi, Pere Serra, and Francesco Maria Chelli. 2019. Exploring the spatial structure of housing prices under economic expansion and stagnation: The role of socio-demographic factors in metropolitan Rome, Italy. *Land Use Policy* 81: 143–52. [CrossRef]
Schwizer, Urs. 1985. Fiscal independence, spillorers and residental choice. *Regional Science Association* 56: 59–70. [CrossRef]
Shaban, Abdul, Karima Kourtit, and Peter Nijkamp. 2022. Causality between urbanization and economic growth: Evidence from the Indian States. *Frontiers in Sustainable Cities* 4: 901346. [CrossRef]
Siampos, George S. 1993. *Demography*. Athens: Smpilias Publishers.
Sun, Xuesong, and Zaisheng Zhang. 2021. Coupling and coordination level of the population, land, economy, ecology and society in the process of urbanization: Measurement and spatial differentiation. *Sustainability* 13: 3171. [CrossRef]
Turok, Ivan, and Gordon McGranahan. 2013. Urbanization and economic growth: The arguments and evidence for Africa and Asia. *Environment and Urbanization* 25: 465–82. [CrossRef]
van de Berg, Leo, Roy Drewett, Angelo Rossi, and Leo Vijverberg Klaassen. 1982. *A Study of Growth and Decline*. Oxford: Pergamon Press.
Vinci, Sabato, Gianluca Egidi, Rosanna Salvia, Antonio Gimenez Morera, and Luca Salvati. 2022. Natural population growth and urban management in metropolitan regions: Insights from pre-crisis and post-crisis Athens, Greece. *Urban Studies* 59: 2527–44. [CrossRef]
Vining, Daniel R., Jr., and Thomas Kontuly. 1977. Increasing returns to city size in the face of an impending decline in the sizes of large cities: Which is the bogus fact? *Environment and Planning A* 9: 59–62. [CrossRef]
Vining, Daniel R., Jr., and Thomas Kontuly. 1978. Population dispersal from major metropolitan regions: An international comparison. *International Regional Science Review* 3: 49–73. [CrossRef] [PubMed]
Yang, Chen, and Shuqing Zhao. 2022. Urban vertical profiles of three most urbanized Chinese cities and the spatial coupling with horizontal urban expansion. *Land Use Policy* 113: 105919. [CrossRef]
Zambon, Ilaria, Andrea Colantoni, and Luca Salvati. 2019. Horizontal vs. vertical growth: Understanding latent patterns of urban expansion in large metropolitan regions. *Science of the Total Environment* 654: 778–85. [CrossRef]
Zambon, Ilaria, and Luca Salvati. 2019. Metropolitan growth, urban cycles and housing in a Mediterranean country, 1910s–2010s. *Cities* 95: 102412. [CrossRef]

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Reimagining Sustainable Development and Economic Performance Indicators: A Human-Centric Maslow–Bossel Blueprint

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Abstract: Reflecting the shift from purely quantitative economic growth to broader socio-environmental sustainability, this study proposes a framework for assessing sustainable development (SD) by integrating Maslow's hierarchy of needs with Bossel's classification system. As economic development increasingly emphasizes sustainability, numerous organizations and agencies, including the United Nations, have developed indicators to measure sustainable progress. However, subjective dimensions of SD, grounded in individual values and needs, remain underexplored. This study operationalizes Maslow's "pyramid of needs" alongside Bossel's system to establish an "SD pyramid", distinguishing dimensions and indicators that capture social, economic, and environmental complexity. By mapping human needs onto the Sustainable Development Goals (SDGs), this study contributes to delineating (i) the research areas uncovered (or partly covered) with relevant indicators, (ii) a significant lack or partial shortage of pertinent information, and (iii) a combination of a few basic indicators summarizing the necessary information into a unique measure of SD. The outcomes offer a foundation for a quali-quantitative assessment of SD, enhancing the monitoring tools focusing on subjective and contextual needs.

Keywords: sustainable development; performance indicators; sustainability metrics; Maslow's hierarchy; Bossel's classification; economic sustainability; socio-environmental complexity; policy targets; SDGs

1. Introduction

Over recent decades, the concept of sustainable development (SD) (Shi et al. 2019; Vardopoulos and Karytsas 2019) has acquired considerable relevance within the debate of the economic growth and competitiveness of national and regional production systems, becoming a crucial issue in societies grounded in the principles of justice and equity (Guo et al. 2022; Kiseľáková et al. 2019). To this end, the environmental component plays an essential role in eliminating, or, at least, containing, the negative externalities of socioeconomic dynamics on environment quality and ecosystem services (Paprotny 2021; Kapsalis et al. 2019). While the concept of SD mainly focuses on ecological issues (Hariram et al. 2023), especially regarding the management of natural resources and biodiversity (e.g., Zorpas 2014), the notion of SD embraces multiple dimensions of well-being (Cortesi et al. 2022; Vardopoulos et al. 2024a) and territorial justice (Demeterova et al. 2020; Nickayin et al. 2023), which extend to the economic, environmental, and social frameworks of a particular place, community, or production system (Sarvajayakesavalu 2015; Lehtonen 2004).

This notion transcends a purely economic prosperity model strictly associated with monetary indicators like Gross Domestic Product (GDP) growth and capital accumulation (Alaimo and Maggino 2020; Fritz and Koch 2014). The intrinsic development of a given location in non-economic terms is also a measure of economic progress (Lyytimäki et al. 2020; North 1955) and should further incorporate qualitative dimensions, enhancing the social, cultural, and moral well-being of residents (and visitors/tourists) to optimize the quality of life (Li et al. 2020; Wiesli et al. 2021). Several scholars argue that economic growth and environmental sustainability are often seen as competing goals, especially when technological progress or substitution abilities in capital usage are limited (Klaassen and Opschoor 1991; Tsangaris et al. 2024).

Nevertheless, the transition to SD remains essential, underscoring the joint significance of SD's three pillars, namely environment, society, and economy, as they collectively foster synergy and cooperation among different knowledge sectors (Purvis et al. 2019; Jovanović et al. 2023). Studies examining the inter-relations between the economic, social, political, and environmental aspects of SD consistently reveal (explicitly or implicitly) that the Sustainable Development Goals (SDGs) are interdependent and should be pursued in an integrated manner (van Zanten and van Tulder 2021; Fonseca et al. 2020). Increasingly, empirical research scrutinizes whether SDGs operate synergistically or present trade-offs in practice (Luca Salvati and Carlucci 2014; Fonseca et al. 2020).

Sustainable economic growth has been described as an oxymoron within the context of finite resources (El Chami 2021; Callenbach 2014). Economic growth, therefore, should ideally coexist with environmental sustainability, where the reduced exploitation rate of natural resources and lower consumption levels—achieved through "sustainability" policies and practices—may ultimately curb economic growth (Zhang et al. 2022; Hariram et al. 2023). Conversely, initiatives that stimulate economic growth can potentially hinder SD, at least from a classical standpoint (Galindo-Martín et al. 2020; Yin 2019). Development pathways are, thus, linked to improving life quality, regarded as a qualitative precondition for well-being that transcends the boundaries of economic systems (Mouratidis 2021; Cibulka and Giljum 2020).

From an SD perspective, "well-being" can be understood as a specific state of human existence shaped by subjective perceptions, actual environmental conditions, and the interrelationships among all material and immaterial elements within a system (Brulé 2022; Cortesi et al. 2022). To identify connections between well-being and the socioeconomic context, an operational approach is required, one that quantifies and contextualizes the available data (Nagy-Pénzes et al. 2020; Silva et al. 2021).

The ongoing development of a comprehensive, comparable, and unified dashboard of Sustainable Development Indicators (SDIs) aligned with the SDGs has resulted in two major United Nations (UN) initiatives. These initiatives are strong candidates for providing a coherent representation of SD through shared frameworks, relevant conceptual approaches, documented methodologies, and, thus, suitable indicators. Initially, in 2007, the UN, with support from independent scholars, proposed an operational framework that included 50 primary and 46 secondary indicators for monitoring SD. Less than a decade later, in 2015, the institution introduced more advanced approaches, outlining multiple indicators that gauge the progress toward achieving the 17 SDGs (Klopp and Petretta 2017; Giangrande et al. 2019).

While numerous academic contributions have developed indicator systems that evaluate SD from an objective perspective (Loizia et al. 2021; Sateriano et al. 2024; Vardopoulos et al. 2021), subjective analyses—particularly those reflecting individual perceptions—remain underexplored and offer fertile ground for new interdisciplinary insights. Building on this premise, the present study examines the intrinsic relationship between SDGs and SDIs, illustrating the potential for subjective classifications of "needs" to enrich and refine SDIs within the broader framework of the UN's SDGs. Specifically, the operational use of Maslow's hierarchy of needs (Maslow 1943) alongside an original classification system by Bossel (1999) is proposed to collectively define the relevant indicators and condense them into simplified, non-redundant measures of SD, with particular emphasis on their connection with human needs. As previous studies have only partially addressed this connection, this analysis seeks to advance both theoretical and practical understanding, aiming to contribute—preliminarily and conceptually—to a more subjective and individualized evaluation of SD.

This work emphasizes the notion of "subjective needs" as the foundation of any SD path rooted in individual values, aspirations, and necessities. The two approaches—Maslow and Bossel, as elaborated later in this contribution—facilitate the creation of an "SD pyramid", which differentiates specific analytical dimensions and relevant indicators. By presenting examples of indicator classification based on Maslow's and Bossel's frameworks and qualitative criteria, this system enables an exploration of the contributions of various social, economic, and environmental complexities to SD from an individual perspective. The intensity and spatial direction of changes over time in the selected indicators, as well as their placement within this pyramid, are particularly relevant aspects warranting continuous evaluation (Shaker 2015; Wilson et al. 2007). Moreover, this innovative approach strengthens and adds scientific depth to more traditional, objective methodologies, establishing a conceptual linkage between an objective and aggregated (quantitative indicator-based) evaluation of SD and a more subjective and disaggregated perspective grounded in individual needs and qualitative indicators (Fotopoulou et al. 2022; Luan et al. 2017).

This article is organized into five standard sections, which are further divided into thematic sub-sections. Section 2 presents a state-of-the-art examination, addressing the operational concept of SD and the ongoing academic discourse surrounding the SDGs and SDIs (Sections 2.1 and 2.2). Section 3 outlines the theoretical and practical aspects of the proposed approach, including the rationale behind specific examples and applications to global UN indicator dashboards (Section 3.1). This is followed by separate introductions to Maslow's theory (Section 3.2), its natural linkages with the concept of SD (Section 3.3), potential applications to the UN's SDGs (Section 3.4), and Bossel's operational framework for indicator classification (Section 3.5). Section 4 provides specific examples and practical results arising from integrating these conceptual frameworks with the UN's SDGs. Section 5 concludes the article with an extended discussion on the originality and innovation of this approach, its anticipated limitations, and pathways for future research focused on integrating objective and subjective dimensions in assessing SD progress.

2. State-of-the-Art Examination

The concept of SD, as defined in the seminal Bruntland report (1987), has evolved significantly, incorporating various socioeconomic, environmental, and policy dimensions that aim to foster a balanced global society (Díaz-López et al. 2021). The fundamental pillars—society, environment, and economy—form the backbone of SD and are reflected in the 17 goals outlined by the United Nations in its 2030 Agenda. In response to the increasing complexity of SD, a wide array of indicator systems has been developed, providing both granular and composite measures of SD progress (Schoenaker et al. 2015; Huan et al. 2021).

For example, the Human Development Index (HDI) encapsulates a multi-faceted view of human well-being by measuring life expectancy, education, and per capita gross national income (Ghislandi et al. 2019). The HDI, with its simplicity, has inspired derivative indicators like the Inequality-adjusted HDI (IHDI), the Gender Development Index (GDI), and the Gender Inequality Index (GII) (Land 2015). These adaptations account for disparities, such as gender inequality and poverty, which affect SD paths (Nilsson and Larsen 2020). Additionally, the Multidimensional Poverty Index (MPI) captures the deprivations that individuals face across several dimensions, further highlighting the need for holistic SD metrics (Alkire and Sumner 2013; Alkire et al. 2022). In the environmental sphere, notable indicators include the Ecological Footprint (EF), which assesses the area required to sustain resource consumption, and the Environmental Performance Index (EPI), which focuses on ecosystem health and human environmental safety (Strezov et al. 2017). Indicators like the City Development Index (CDI) and the City Prosperity Index (CPI) extend SD evaluations to urban settings, addressing the specific sustainability challenges of metropolitan areas (Wong 2015).

As these frameworks expand, the development of composite indexes—such as the Measure of Economic Welfare (MEW) and the Genuine Progress Indicator (GPI)—has gained prominence, allowing for more comprehensive comparisons across regions and socioeconomic contexts (Zambon et al. 2017). These indexes, while valuable, often necessitate adaptation to the specific socioeconomic and environmental contexts of the areas under evaluation, thus limiting their generalizability on a global scale.

2.1. Operational Notion of "Sustainable Development" and Key Indicators

Indicators have evolved to represent a broad spectrum of sustainability measures (Hueting and Reijnders 2004). Systems such as the HDI emphasize human development, while indexes like the Environmental Performance Index (EPI) focus on environmental outcomes (Liu et al. 2017). Collectively, they allow for inter-country and inter-regional comparisons of sustainability progress (Liu et al. 2017). Despite their advantages, (these) indicators often fall short of capturing the intricate interactions across SD dimensions, such as the synergy or trade-offs between economic growth and environmental sustainability (Bali Swain and Yang-Wallentin 2020).

Recent studies advocate for a multidimensional approach to SD evaluation, employing tools such as the AHP (Analytic Hierarchy Process) (Vardopoulos et al. 2021) and fuzzy logic (Vardopoulos 2019) to capture the inter-relations among the SD pillars: social, environmental, and economic. These tools offer a sophisticated means of assessing SD across scales, highlighting the contextual relevance of indicators to local and regional sustainability efforts (Carlsen and Bruggemann 2022).

Generally speaking, these indicators have been adopted for specific socioeconomic (or territorial) conditions, e.g., at a sectoral or national level, thus preventing a possible generalization to broader contexts.

2.2. Maslow's Pyramid and Sustainable Development Indicators

Maslow's hierarchy of needs has been adapted in SD studies to frame human well-being as a central pillar of sustainability (Yawson et al. 2009). Traditionally structured as a pyramid progressing from basic physiological needs to self-actualization, Maslow's framework serves as a lens for evaluating human development within sustainable practices.

In recent years, Maslow's hierarchy has been applied to SD frameworks as a tool for categorizing indicators within human-centered SD. The progression of needs—from physiological to self-actualization—has been particularly useful in evaluating human-centric SD goals, such as poverty reduction (SDG 1) and well-being (SDG 3). At higher levels, Maslow's hierarchy aids in assessing the goals related to social stability and governance, such as SDG 16 (peace, justice, and strong institutions). This hierarchical structure effectively aligns with SD, facilitating the inclusion of qualitative dimensions such as social well-being and individual self-fulfillment within sustainability evaluations.

As SD indicators evolve, a systems-oriented approach enables the integration of both objective and subjective measures. Bossel's systems-thinking framework, which emphasizes interconnected societal and environmental systems, offers a holistic model for designing SD indicators. By classifying indicators according to criteria like adaptability, security, and compatibility, Bossel's framework facilitates the development of SD indicators that reflect complex social–environmental interactions. This approach provides an operational basis for assessing SD comprehensively, acknowledging both individual and systemic factors that contribute to sustainability (Bossel 1999).

3. Methodology

Identifying effective methods to measure and compare SD across regions and countries is essential for jointly assessing the environmental, social, and economic performances of specific locations, both historically and in the present, and for designing impactful interventions for the future (Rosati and Faria 2019). Over the years, significant initiatives have been led by the Organization for Economic Cooperation and Development (OECD), the World Bank, and the United Nations Commission. A key milestone was the Rio+20 Conference, where a comprehensive framework for SD was established, addressing specific environmental concerns and socioeconomic topics such as poverty, sustainable cities, employment, education, and inequality (Panagiotopoulos et al. 2022; Díaz-López et al. 2021). In 2015, the United Nations formalized 17 SDGs within "Agenda 2030", aiming to establish a global SD trajectory through a collective global effort by 2030 (Mindrinos and Panagiotopoulos 2023; Koundouri et al. 2024) (Figure 1).

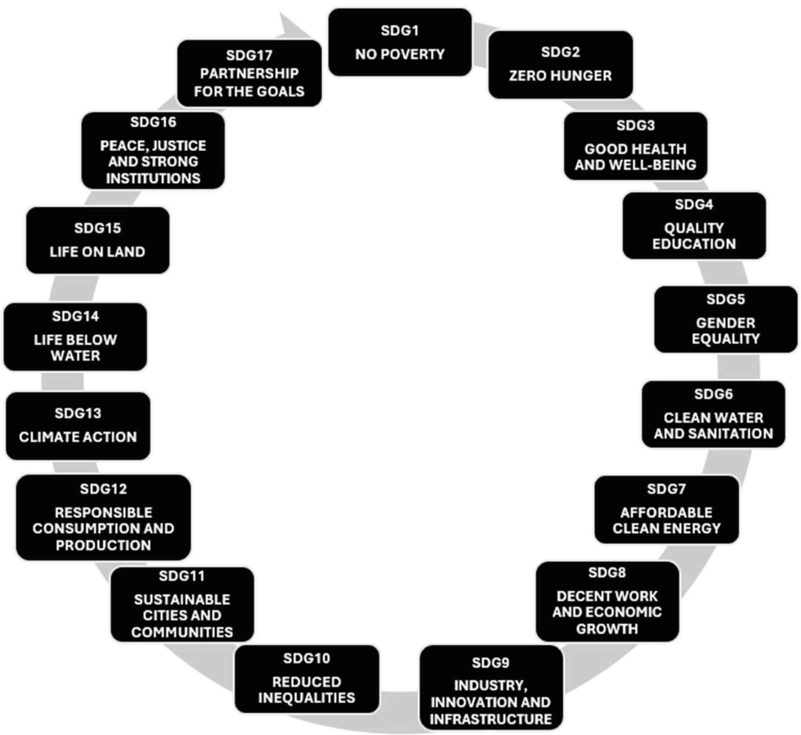

Figure 1. United Nations Agenda 2030: the 17 Sustainable Development Goals.

3.1. Definition and Measurement of Sustainable Development Goals (Agenda 2030)

The SDGs are intended to reinforce and achieve the targets set by leaders from 189 UN countries in the Millennium Development Agenda of 2000 (Vandemoortele 2011; Suresh and Johnson 2015). Agenda 2000 established eight Millennium Development Goals (MDGs) to be achieved by 2015, focusing on critical issues such as reducing extreme poverty and hunger, combating violence against women, and safeguarding health and the environment (Sachs 2012; Lomazzi et al. 2014) (Figure 2). The development and implementation of the SDGs occurred in a markedly different context than that of the MDGs. Unlike the MDGs, which were formulated by a group of experts at the UN headquarters (Unterhalter and Dorward 2013), the SDGs emerged from extensive consultations within individual countries and through face-to-face meetings (Caballero 2019). Technically speaking, the MDGs consisted of 8 goals, 21 targets, and 63 individual indicators (Jacob 2017), with none explicitly addressing human rights. In contrast, the SDGs include seven explicit targets for people with disabilities, six for individuals in vulnerable contexts, and two goals addressing discrimination, among others (Dada et al. 2023). Additionally, while the MDGs primarily focused on developing countries funded by developed nations (J. Sachs and McArthur 2005), the SDGs apply universally to both developed and developing countries, jointly committed to achieving the established goals (Ali et al. 2023). The SDGs center on five core themes, known as the "five P's": people, planet, prosperity, peace, and partnership (Dulume 2019; Tremblay et al. 2020). These themes encapsulate the key issues of the 2030 UN Development Agenda and are associated with multiple SDGs to foster a healthier and more prosperous world (Costa et al. 2021; Fonseca et al. 2020) (Figure 3).

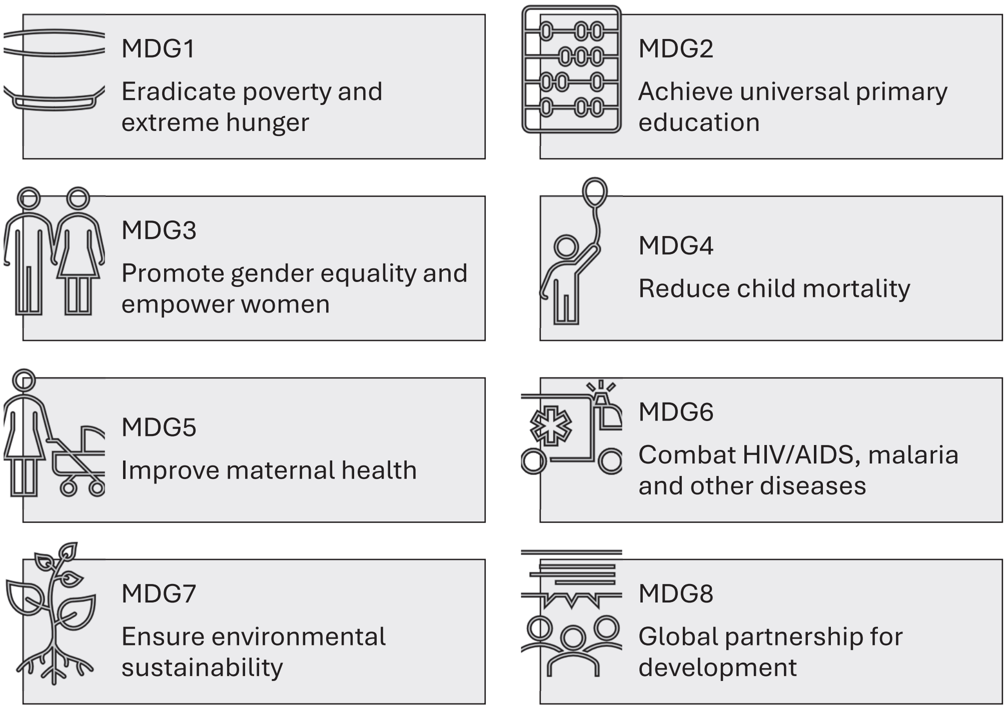

Figure 2. A graphical representation of the MDGs of United Nations Agenda 2000.

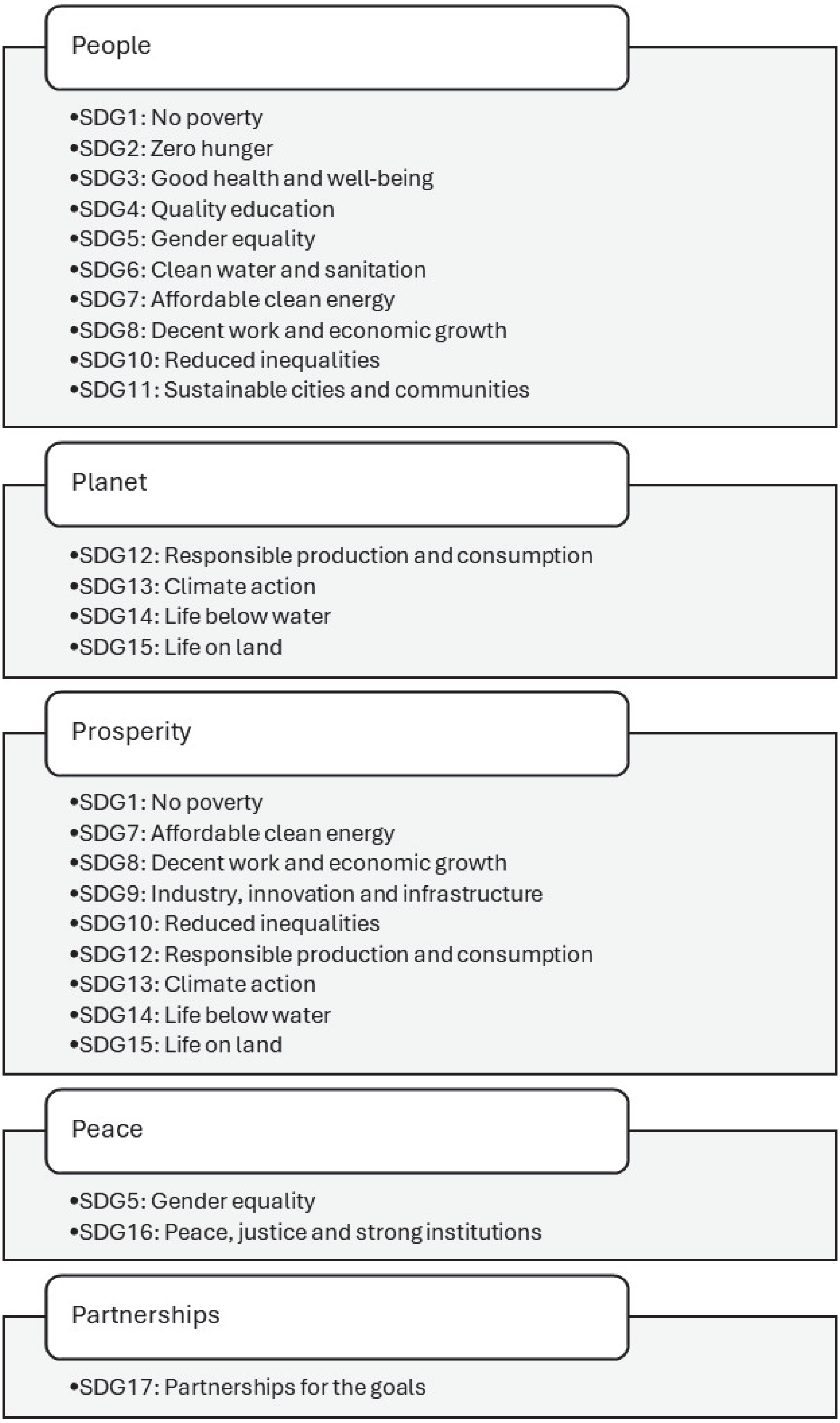

Figure 3. The five keys ('P') of SD and the explicit linkage with SDGs.

The first ‘P’, people, emphasizes the importance of individuals within societies and is connected to key issues like social inclusion and reducing disparities, such as those based on gender. This dimension encompasses targets related to eradicating poverty and hunger (SDG1 and SDG2) (Pérez-Peña et al. 2021; Galabada 2022), achieving better health outcomes (SDG3) (Mikuła et al. 2024), providing quality education (SDG4) (Khan et al. 2022; Eliades et al. 2022), and improving access to clean water and sanitation (SDG6) (Martínez-Córdoba et al. 2020; Tsani et al. 2020). The goals aim to enhance well-being and equality for all, irrespective of social class, gender, nationality, or living conditions (SDG5 and SDG10) (Horton 2015; Fonseca et al. 2020). Additionally, an improved living environment implies access to decent work (SDG8) (Bieszk-Stolorz and Dmytrów 2023; Kavouras et al. 2022), clean energy (SDG7) (Tsangas et al. 2023; Vardopoulos et al. 2023a), and the development of sustainable cities and communities (SDG11) (Stefanou and Miitoula 2024; Vardopoulos et al. 2023b).

The second ‘P’, planet, focuses on protecting natural environments and enacting measures to address climate change. This includes policies aimed at promoting responsible consumption and production (SDG12) (Zorpas 2020b; Kritikou et al. 2021), climate action (SDG13) (Thapa et al. 2023; Sardianou et al. 2023), the conservation of oceans and marine resources (SDG14) (Xue et al. 2023; Gourgiotis et al. 2024), and efforts to combat land degradation (SDG15) (Maialetti et al. 2024a, 2024, 2024c; Halbac-Cotoara-Zamfir et al. 2020).

The third ‘P’, prosperity, is intrinsically linked to economic growth (SDG8) (Nickayin et al. 2022; Vardopoulos et al. 2024d) and includes social and environmental sustainability (Ali et al. 2023; Sateriano et al. 2024), ensuring benefits for all individuals without discrimination (SDG10) (Cojocaru et al. 2022; Mațcu-Zaharia et al. 2024). This objective also focuses on providing clean energy (SDG7) (Barone et al. 2021; Vardopoulos et al. 2023a) and promoting industrial innovation and infrastructure development (SDG9) (Vardopoulos et al. 2020, 2024c), aiming to preserve and create wealth for future generations (Abrudan et al. 2021).

The fourth ‘P’, peace, seeks to establish a global society free from conflict and violence through principles of universal justice and by promoting strong and accountable institutions (SDG16) (Baranyi et al. 2021). Achieving peace involves eradicating or at least mitigating violence against women and children, as well as all forms of violence (SDG5) (García-Moreno and Amin 2016). A peaceful society is fundamental for social cohesion and SD (Fry and Elliott 2017).

Effective progress toward the 17 goals requires collaborative efforts among governments, academia, and institutions to advance SD, as highlighted in the fifth ‘P’, partnership (SDG17) (Cruz 2023; Bulmer and Yáñez-Araque 2023).

As pointed out in the previous section, the academic literature discussing clear and universally adopted approaches to continuously monitor progress towards the achievement of the SDGs remains limited despite the critical importance of this issue (Ricciolini et al. 2022). Quantitative analyses are also constrained by the extensive scope of the topic, which involves multiple levels and scales of application—national, regional, and global—and by the lack of a standardized lexicon, complicating comparisons across different studies and implementations (Bishop et al. 2016). The need for a new framework to address these challenges, along with technical support using novel tools for conducting ex ante, in itinere, and ex post evaluations of progress toward sustainability across the economic, social, and environmental pillars, has been emphasized (Gusmão Caiado et al. 2018; Scrase and Sheate 2002). Additionally, any mis-specification or omission of variables in an assessment model may lead to biased results and evaluations (Aksoy and Bayram Arlı 2020; Kubiszewski et al. 2022).

Within this framework, support systems play a crucial role in providing essential information, enhancing decision-making processes, and selecting (and measuring) activities that genuinely advance SD pathways (Schmidt-Traub et al. 2017). Numerous studies have been conducted by institutions across various countries (Firoiu et al. 2019). Among them, it has been argued that the current indicators related to SDG10 fall short in quantifying the progress in reducing within-country disparities (Winkler and Satterthwaite 2017), while a comprehensive analysis of the commonly used indicators highlights both advantages and critical issues (Barbier and Burgess 2019). In Canada, sustainability progress was evaluated using an approach grounded in the "no one left behind" principle, excluding non-relevant targets, focusing on the available data, and employing proxies to address missing information (McArthur and Rasmussen 2019). Meanwhile, Australia's progress toward SD has been monitored through selected SDGs (Allen et al. 2020). To highlight differences in evaluation methods for tracking target achievement, a comparison of three distinct approaches used by the Sustainable Development Solutions Network (SDSN), the Economic and Social Commission for Asia and the Pacific (UNESCAP), and the Organization for Economic Cooperation and Development (OECD) has also been conducted (Bidarbakhtnia 2020).

An alternative set of indicators, partly inspired by the aforementioned approaches, includes composite indexes of SD (Zhou et al. 2012). These indexes are often used to quantify complex, multidimensional concepts—such as economic, social, and environmental aspects of sustainability—and facilitate straightforward, intuitive comparisons across different regions and territories (Bonnet et al. 2021). When well designed and managed, they enable the handling of vast amounts of data from individual indicators with minimal loss of informational detail (Delli Paoli and Addeo 2019). For instance, a composite index based on SDG9 was developed to monitor industrialization progress across 128 global economies from 2000 to 2016, addressing key sustainability aspects such as social inclusiveness and environmental impact (Kynčlová et al. 2020). Similarly, a set of composite indexes has been applied to evaluate sustainable city initiatives in Spain, with outcomes influenced by the compensability levels in the aggregation of individual indicators (Lo-Iacono-Ferreira et al. 2022). Given the breadth of SDG targets and indicators, aggregation plays a crucial role in evaluating and monitoring sustainability progress. However, the selection and operationalization of indicators continue to present significant challenges. Experts emphasize the need for a clear conceptual framework and specific references to ensure indicator relevance and effectiveness, underscoring the enduring value of foundational guidance provided in earlier work (Hák et al. 2016; Lancker and Nijkamp 2000).

3.2. Maslow's Theory and the Operational Use of "Pyramid" Tools

Maslow developed a theory on human needs satisfaction, proposing that while each person is unique, all individuals share fundamental needs whose fulfillment enables the attainment of well-being (Maslow 1943). Maslow's framework categorizes human needs within a hierarchical structure, indicating their progressive priority (Mathes 1981). He represented this hierarchy as a pyramid, where the base comprises the most instinctive and essential needs, such as physiological needs for food, health, and safety (Bridgman et al. 2019). The higher levels encompass "emotional" and "social affirmation" needs, reflecting an existential state that surpasses basic requirements (Montag et al. 2020). Although the concept of "need" is often associated with the individual or subjective domain, well-being is ultimately achieved within a broader socio-environmental context (Kenrick et al. 2010).

Each individual needs to adjust their expectations and behaviors to align with the social norms, resource availability, and environmental constraints of their community (Forsyth 2013; Vasseur et al. 2022). This adjustment reflects a stratified expression of social (Perry et al. 2021), demographic (Luca Salvati et al. 2019), cultural (Cardenas 2011), institutional/political (Doukas et al. 2023), economic (Yamin et al. 2019), and ecological (Everard et al. 2016) factors that may restrict personal desires within the "carrying capacity" of the socio-environmental system (Cardenas 2011; Yamin et al. 2019). Within this complex system, an optimal balance can be achieved by incorporating specific knowledge of landscapes, environments, ecosystems, and ecological conditions into the socioeconomic evaluation of "needs", alongside implementing collective, rather than individualistic, strategies aimed at enhancing well-being (van den Bosch and Sang 2017). Human needs should be realistically achievable within a framework of "fair", "sustainable", and, above all, "long-lasting" well-being (Khraisha 2020). Consequently, individual well-being is inherently influenced by physical and social environments, and achieving the stages of Maslow's hierarchy (progressively represented in succession) is only feasible within an adequately "holistically healthy" territorial context (Repetti 1987).

To this end, the objective quality of a given territory should be connected with the subjective aspects of well-being (Costanza et al. 2007). Several indexes have been developed to express both the territorial dimension, in terms of a territory's health or degradation, and the social and individual dimensions of well-being (Tomaselli et al. 2021; Perchinunno et al. 2020). The environmental–territorial dimension can be analyzed through objective indexes, such as the Environmentally Sensitive Areas Index (ESAI) (Luca Salvati et al. 2015), or thematic indexes that measure factors like the prevalence of illegal buildings (Luca Salvati et al. 2013), the demographic makeup of unauthorized real estate units (Vinci et al. 2023), the rate and spatial patterns of urbanization in areas under landscape protection, the erosion of rural and semi-natural spaces due to urban sprawl (Vardopoulos et al. 2024b), the decline of rural areas due to land abandonment (Doukas et al. 2022), the presence of green spaces in urban settings (Bianconi et al. 2018), and the severity of air (Kougea and Koundouri 2011), water (Frontistis 2021), and soil pollution (Zorpas 2020a). Indicators for these dimensions are often derived from sample surveys, official statistics on aspects of daily life, or interviews with key informants representing a cross-section of society, conducted across various scales from aggregated (national and regional) to disaggregated (local communities, municipalities, neighborhoods, and individuals) levels.

3.3. The Evolution of Maslow's "Theory of Needs" and Sustainable Development

The Brundtland Report's definition of SD encourages individuals to meet their own needs without compromising the needs of future generations (Kuhlman and Farrington 2010). Within this framework, constraints such as the current state of technology, environmental conditions, and social structures play crucial roles in shaping sustainable economic growth (Lans Bovenberg and Smulders 1995; Rojas et al. 2023). Ensuring that essential needs are met across populations remains a guiding principle for government policies aimed at equitable resource distribution, supporting both affluent and disadvantaged nations in reducing poverty (Udo and Jansson 2009; King 1998). Additionally, wealthier countries are encouraged to adopt eco-friendly policies and invest in innovations that promote the sustainable use of resources, addressing climate change while prioritizing intergenerational equity (Ahmad and Wu 2022).

Maslow's 1943 "Theory of Needs" provides a socio-political model useful for analyzing the SDGs both qualitatively and quantitatively. Traditionally, Maslow's model categorizes human needs in a hierarchical structure, starting from basic physiological needs and ascending through safety, love and belonging, esteem, and, ultimately, self-actualization (Mathes 1981). The theory was expanded in 1971 to include three additional levels: cognitive needs, aesthetic needs, and self-transcendence (Koltko-Rivera 2006; Kenrick et al. 2010). However, contemporary critiques highlight that Maslow's original model is somewhat static and does not fully account for the dynamic needs of modern societies, particularly with the emergence of new social, environmental, and digital dimensions that shape human well-being (Taneva 2023; Harvard 2010).

In response to these critiques, a refined classification has been proposed that integrates digital advancements and social shifts into Maslow's hierarchy. For instance, digital connectivity is now recognized as a fundamental component of both safety and belonging (Benson and Dundis 2003), with the potential to influence esteem needs as well. In the digital age, access to information and online networks supports individual security (digital safety and data privacy), fulfills social needs (online social connections and communities), and even contributes to self-esteem (social media engagement and virtual recognition) (Cao et al. 2013; Ghatak and Singh 2019). This expanded model reflects the increasingly interconnected nature of digital needs within Maslow's hierarchy, illustrating how digital access influences well-being on multiple levels and aligning with the SDGs that focus on equality and inclusive access (Yildiz 2021).

Accordingly, the following updated classification addresses both traditional and contemporary needs, integrating digital aspects that are central to 21st-century lifestyles (Griskevicius et al. 2006) (Figure 4):

- Physical and psychological needs: this base level encompasses nutrition, healthcare, sleep quality, and physical activity, forming the foundation of individual health and well-being.
- Safety needs: beyond physical security, financial stability, and health, modern safety needs now include digital safety—encompassing data privacy, cybersecurity, and the safe use of digital technologies—which are critical in today's digital society.
- Need for belonging: social connections, family, and romantic relationships are joined by digital communities and social media, which fulfill a growing aspect of individuals' need to connect with others in virtual spaces.
- Need for esteem: traditional esteem needs related to achievement and recognition now include online validation, such as social media engagement, which has become an influential factor in self-perception and confidence.
- Cognitive needs: knowledge, curiosity, and understanding remain key, but modern information access, such as digital learning platforms and online resources, is crucial in meeting these needs today.
- Aesthetic needs: the appreciation of beauty, enhanced by digital access to art and nature through virtual media, aligns with contemporary expressions of aesthetic fulfillment.
- Self-actualization needs: creativity, personal fulfillment, and meaning continue to define this level, with the internet providing expanded avenues for creative exploration, career development, and lifelong learning.
- Self-transcendence needs: the pinnacle of the pyramid, focusing on self-transcendence, is enriched by the digital era, allowing individuals to form global connections and engage in collaborative projects that transcend personal identity and contribute to broader societal goals, aligning with the SDGs related to global partnerships and social inclusion.

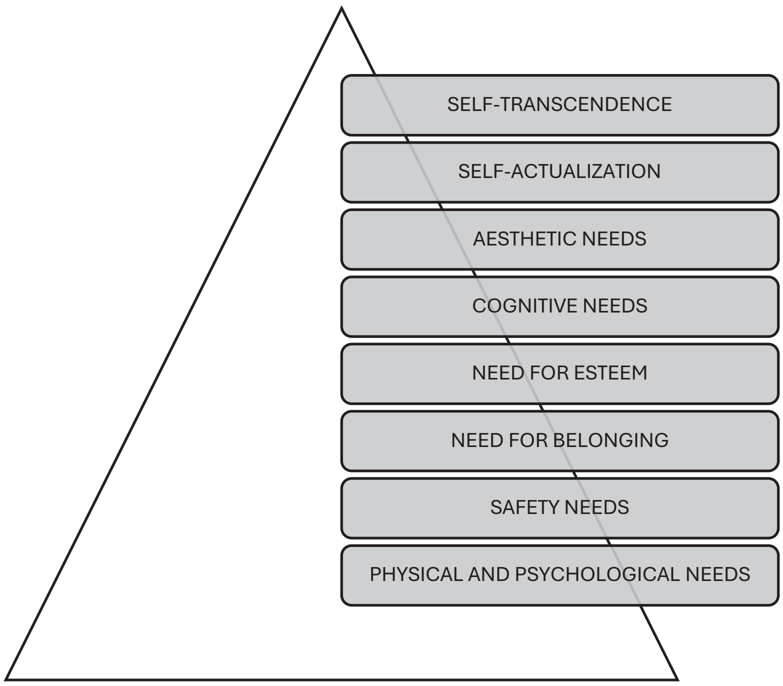

Figure 4. The pyramidal hierarchy of needs as envisaged in Maslow's theory.

3.4. The Intimate Linkage Between Maslow's "Pyramid of Needs" and Agenda 2030 SDGs

The Brundtland report's definition of SD highlights the connection between Maslow's theory of human needs and the Agenda 2030 SDGs (Cheshmehzangi and Zou 2024; Zhai et al. 2023). Fundamental needs like nutrition are critical to achieving the SDGs, impacting healthcare, education, and women's empowerment (Wells et al. 2020). Addressing nutrition helps break poverty cycles, as sound policies improve community well-being in both developed and developing countries (Aliyu et al. 2021). In wealthier nations, dietary choices consider environmental impacts, aiding climate mitigation (Ribeiro Hoffmann et al. 2024). Sustainable fishing practices also align with the "life below water" SDG, supporting water quality and sanitation improvements (Atkinson and Cools 2017). Nutrition interlinks with multiple SDGs: sustainable diets affect climate change (Koliaki et al. 2024), biodiversity (Belgacem et al. 2021), and water quality (Tompa et al. 2022); quality nutrition enhances health and productivity (Alt et al. 2022; Grimani et al. 2019); and proper diets improve well-being and women's empowerment, leading to reduced poverty and inequalities (Huang et al. 2023).

Education, a cognitive need from Maslow's later model, is a fundamental right and a driver of economic development, healthcare, and social empowerment ("Education" 1964). It reduces inequalities (SDG10) (Cojocaru et al. 2022) and supports poverty reduction (SDG1). Education also impacts health (SDG3) (Fonseca et al. 2024), as knowledge helps manage diseases and fosters strong institutions (SDG16) for peace and reduced unemployment (SDG8) (Mehmetaj and Xhindi 2022).

3.5. Bossel's Theory to Design Sustainable Development Indicators

Operationally, SD is defined as a developmental pathway that fully aligns with sustainability criteria (Wojtkowiak and Cyplik 2020). The concept is inherently dynamic, as it must adapt to social transformations in culture, technology, and economic expectations while often reflecting an unpredictable evolutionary process (Wibeck et al. 2019; Vardopoulos et al. 2023b). Evaluating progress, along with its actual or anticipated impacts, requires a comprehensive set of indicators that describe the state of the environments and systems shaping society (Ramos 2019; Pappas et al. 2021). The pursuit of effective SD indicators has been ongoing across various levels of social organization, from local communities to the global scale (Salvati et al. 2008; Vardopoulos et al. 2018). Within scientific discourse, scholars contend that no single indicator can capture the full scope of SD; instead, multiple indicators are necessary to encompass all relevant dimensions in any specific application (Luca Salvati and Zitti 2009; Ferrara et al. 2012).

Historically, indicator selection was conducted by specialists in fields such as economics, ecology, sociology, and engineering (Inglezakis and Zorpas 2014; Pissourios 2013). This approach often resulted in discipline-biased indicators that emphasized field-specific aspects while overlooking essential broader features (Heckman et al. 1998). To address these limitations, Bossel (1999) proposed a robust research framework, defining SD as an evolutionary process of interacting systems within a shared environment, where each system self-organizes to meet the unique challenges of its surroundings. The intricate network of interacting systems can be recursively decomposed into individual systems, each influencing its own trajectory and that of others (Hjorth and Bagheri 2006; Ostrom 2009). The performance of each specific system, along with its interaction mechanisms with others, should be assessed using one or more indicators (Reed et al. 2005). The design of these indicators begins with identifying essential systems and subsystems, thereby establishing the structure and characteristics of an "ideal" system (Reed et al. 2005). Next, statistical methods are applied to aggregate and condense the selected indicators while preserving crucial information.

In this framework, the selected indicators are assumed to fully capture each system's fundamental interests according to six core criteria aligned with Bossel's framework and guided by Maslow's hierarchy of needs: (i) existence, (ii) effectiveness, (iii) freedom of action, (iv) safety, (v) adaptability, and (vi) psychological coexistence (for systems involving human elements). Using these criteria, a comprehensive and minimal set of indicators has been developed to provide insights into all aspects of viability and sustainability (Table 1).

Table 1. A recursive scheme to design viable indicators of SD (own elaboration on Bossel (1999) and incorporating additional indication from Maslow's theory).

Basic Dimension	Viability of Affecting System	Contribution to Affected System
Existence	Is the system compatible with and can it exist in its particular environment?	Does the system contribute its part to the existence of the affected system?
Effectiveness	Is it effective and efficient?	Does it contribute to the efficient and effective operation of the total system?
Freedom of action	Does it have the necessary freedom to respond and react as needed?	Does it contribute to the freedom of action of the total system?
Security	Is it secure, safe, and stable?	Does it contribute to the security, safety, and Stability of the total system?
Adaptability	Can it adapt to new challenges?	Does it contribute to the flexibility and adaptability of the total system?
Coexistence	Is it compatible with interacting subsystems?	Does it contribute to the compatibility of the total system with its partner systems?
Psychological needs (for specific systems)	Is it compatible with psychological needs and culture?	Does it contribute to the psychological well-being of people?

The systems-oriented approach appears effective in defining a comprehensive set of indicators for SD, as it leverages existing datasets while minimizing the risk of overlooking essential aspects or overemphasizing minor ones (Reed et al. 2005). This approach is particularly valuable when evaluating sustainability under time and budget constraints. Generally, selecting supplementary indicators to validate existing ones is advisable, especially for large-scale projects, as it enables the development of relevant indicators for new or less-experienced practitioners (Bagheri and Hjorth 2007). The systems-oriented approach has significant potential to influence the selection and application of SD indicators across various domains, including technical, institutional, and public sectors (Barbier and Burgess 2017). This method provides an overarching framework and guidelines for designing a complete, reliable set of indicators, focusing data collection on essential information and, thus, facilitating the exchange of foundational knowledge and practical experiences among agencies and via digital platforms (Bradley Guy and Kibert 1998). Moreover, this approach enhances the capacity of the public, administrations, and businesses to accurately interpret and apply the selected SD indicators.

Overall, the systems-oriented approach has proven to be a valuable and systematic tool for selecting SDIs, improving the efficiency of sustainability assessments, and facilitating the practical application of indicators across various contexts (Pokorný and Palacká 2023). It provides a robust foundation for comparative approaches that encompass all essential aspects of SD (van Zanten and van Tulder 2021).

4. Results

As discussed in previous sections, SD fundamentally involves meeting the needs of both present and future generations (Kuhlman and Farrington 2010). To achieve this, these needs must be accurately identified and quantified using indicators or composite indexes (Mindrinos and Panagiotopoulos 2023; Inglezakis and Zorpas 2014). While prior work has often focused on organizations and institutions, sustainability originates at the individual level (Doukas and Vardopoulos 2023). Based on this foundational premise, sustainability in a rapidly changing world must advance in tandem with SD (Bossel 1999). Ongoing transformations in economic, social, and environmental spheres may challenge the adaptability and resilience of the global system. Achieving the SDGs requires provisions across three primary areas—economy, society, and environment—and within six operational subsystems of human life, addressing the needs of individuals and society as a whole, from basic to secondary needs (J. D. Sachs et al. 2019).

Profiling SDIs According to Maslow's Pyramid and Bossel's Theory

The sustainability of the overall system depends on the functionality and viability of each of its subsystems. Maintaining this condition requires designing effective indicators that provide insights into each subsystem's contribution to the sustainability of the global system. Table 2 aligns the standard models of Bossel (1999), Maslow (1943), and the UN 2030 Agenda, operationally highlighting correspondences between fundamental human needs and SDGs. While these examples represent only a fraction of the many linkages among deeply interconnected processes, the connections reveal that they support a deeper understanding of the relationships among various aspects of SD and human needs—at physical, social, and psychological levels. They also illustrate the link between efforts to achieve SDGs and the effective fulfillment of both fundamental and higher human needs, individually and collectively.

Table 2. An exemplified classification of SDGs based on Bossel's and Maslow's operational schemes.

Bossel (1999)		**Maslow (1943)**	**2030 UN AGENDA**
HUMAN SYSTEM	Individual development Social system	Physical and psychological needs Safety needs Cognitive needs Need for esteem Self-transcendence	SDG1: No poverty SDG2: Zero hunger SDG3: Good health and well being SDG4: Quality education SDG5: Gender equality SDG10: Reduced inequalities SDG12: Responsible production and consumption
	Government	Safety needs Need for esteem Self-transcendence	SDG16: Peace, justice and strong institutions SDG17: Partnerships for the goals
SUPPORTSYSTEM	Infrastructure	Physical and psychological needs Need for belonging Need for esteem Aesthetic needs	SDG9: Industry, innovation and infrastructure SDG11: Sustainable cities and communities
	Economic system	Physical and psychological needs Self-actualization	SDG8: Decent work and economic growth SDG9: Industry, innovation and infrastructure SDG11: Sustainable cities and communities
NATURAL SYSTEM	Resources and environment	Physical and psychological needs	SDG6: Clean water and sanitation SDG7: Affordable clean energy SDG13: Climate action SDG14: Life below water SDG15: Life on land

The first operational area, associated with the "human system", emphasizes the strong interconnection between the SDGs and fundamental human needs, aligning with the lower and middle tiers of Maslow's pyramid and broadly encompassing the dimensions of "individual development", "social systems", and "governance". In this context, physical and psychological needs, safety, self-esteem, and self-transcendence correlate closely with various SDGs, including poverty reduction (SDG1), hunger eradication (SDG2), and health promotion (SDG3). The "governance" dimension underscores the importance of societal stability in fulfilling these essential needs. Accordingly, safety and self-transcendence needs are logically linked to SDGs that promote peace, justice, and strong institutions (SDG16), as well as global partnerships (SDG17).

The second area pertains to the support system, which includes "infrastructure" and the "economic system", recognizing that high-quality infrastructure meets not only physical needs but also social and psychological ones. Infrastructure addresses physical and psychological needs, belonging, esteem, and aesthetic requirements and aligns with SDGs focused on sustainable infrastructure (SDG9) and sustainable communities (SDG11). The economic system supports self-actualization by fostering economic growth, decent work (SDG8), welfare, and individual development.

The third area involves natural systems, being closely connected with "resources", the "environment", and "ecosystems", highlighting the critical role of a healthy environment in overall well-being. In this context, physical and psychological needs are intrinsically linked to SDGs that focus on sustainable resource management, including clean water (SDG6), affordable clean energy (SDG7), and environmental conservation (SDGs 13, 14, and 15).

Based on the key systematization in specific dimensions and the explicit linkage with the UN's SDGs, as reported in Table 2, a final effort was made in Table 3 to make more explicit and, thus, fully operational, Bossel and Maslow's scheme into statistical themes (dimensions) corresponding with defined indicators routinely derived from official statistics. In the case of the table, we considered a representative production of subjective indicators for a continental area (European Union) primarily based on a comparative, high-quality sampling design valid in all member countries and carried out under a representative sample of the residents interviewed, using a defined and stable questionnaire that investigates a vast number of self-perceived aspects of sustainable development and quality of life. The indicators proposed in the table were produced and released coherently every year, generally since the early 2000s, and covering Europe at a particularly refined scale (basically, macro-regional and/or regional level) over a sufficiently long time interval (generally since the early 2000s). While improvable in several directions—when they are made available from official statistics—the ensemble of subjective indicators illustrated in Table 3 may represent a particularly vast, stable, and robust set of variables, forming a composite evaluation of sustainable development, fully adhering to the principles of Bossel and Maslow and anchored on fully comparable, standardized, and reliable input information based on Eurostat EU-SILC, the European System of Statistics (both census and sampling frame) on income and living conditions. A coherent scrutiny of such indicators over both time and space may offer a particularly rich evaluation of sustainable development advancements in a vast set of territories, with different socioeconomic characteristics, in Europe, and provide an explicit indicators dashboard that can be updated regularly and with no effort from official statistics (Eurostat website). Finally, computation on such indicator dashboards may allow for the construction of one (or more) composite indexes of sustainable development using—likely for the first time in the academic literature—a fully subjective perspective *à la* Maslow–Bossel.

Table 3. An exemplified assessment of Bossel and Maslow's operational scheme (see Table 2) considering practical indicators derived from Eurostat official statistics covering the whole of Europe at the macro-regional and/or regional level over a sufficiently long time interval (generally since the early 2000s).

Bossel (1999)		Maslow (1943)	Theme	Indicators
HUMAN SYSTEM	Individual development	Physical and psychological needs Safety needs Cognitive needs Need for esteem Self-transcendence	Overall experience of life (life satisfaction and affects)	Overall life satisfaction by sex, age, and educational attainment Persons being happy in the last 4 weeks by sex, age, educational attainment, and frequency
	Social system		Social interactions (relations with people, activities for people, social support, and social cohesion)	Persons getting together with family and relatives or friends by income quintile, household composition, degree of urbanization, and frequency Persons having contact with family and relatives or friends by income quintile, household composition, degree of urbanization, and frequency Persons having someone to ask for help by sex, age, and educational attainment Persons having someone to discuss personal matters by sex, age, and educational attainment
	Government	Safety needs Need for esteem Self-transcendence	Physical safety Social interactions (relations with people, activities for people, social support, and social cohesion) Governance and basic rights	Police-recorded offenses by offense category Crime, violence, or vandalism in the area Trust in others by sex, age, and educational attainment Level of trust in institutions by sex, age, educational attainment, and domain Gender pay/employment gap Persons participating in formal/informal voluntary activities or active citizenship by income quintile, household composition, and degree of urbanization
SUPPORT SYSTEM	Infrastructure	Physical and psychological needs Need for belonging Need for esteem Aesthetic needs	Quantity of, quality of, and access to leisure Educational attainment, self-reported skills, lifelong learning, and opportunities for education Access to healthcare	Persons not participating in cultural or sport activities in the last 12 months by sex, age, educational attainment, activity type, and reasons Early leavers from education and training by sex and labor status Individuals' levels of digital skills Self-reported unmet needs for medical examination by sex, age, main reason declared, and educational attainment level
	Economic system	Physical and psychological needs Self-actualization	Economic security (wealth and debts)	Inability to face unexpected financial expenses Arrears (mortgage or rent, utility bills, or hire purchase) Labor transitions by employment status Participation rate in education and training
NATURAL SYSTEM	Resources and environment	Physical and psychological needs	Natural and living environment (pollution, landscape, and built environment)	Pollution, grime, or other environmental problems Noise from neighbors or from the street Satisfaction of landscape by sex, age, educational attainment, and domain

5. Discussion

While academic contributions have developed various indicator systems, primarily evaluating SD from an objective standpoint (Krank et al. 2013; Eustachio et al. 2019), the subjective analysis of SD advancements—particularly from an individualistic perspective—remains underexplored and potentially open to interdisciplinary contributions. Building on this premise, the present study examines the intrinsic relationship between SDGs and SDIs by offering selected examples of a subjective classification of "needs" (e.g., Maslow's pyramid of needs) to enrich and refine SDIs within the broader context of the UN's SDGs, in alignment with a logical classification framework such as Bossel's. Specifically, this study proposes an operational application of Maslow's "pyramid of needs" alongside Bossel's classification system to define relevant indicators and condense their information into simplified, non-redundant measures of SD, with a special emphasis on the connection between SD and human needs. This linkage, which has only been partially addressed in previous research (Fu et al. 2020; Mindrinos and Panagiotopoulos 2023; Yawson et al. 2009), is explored here in both theory and practice to contribute—preliminarily and conceptually—to a more subjective and individual evaluation of SD.

In practice, this work centers on the concept of "subjective needs", viewed as the foundation of any SD path rooted in individual values, aspirations, and necessities (Jolibert et al. 2014). The two approaches—Maslow's hierarchy and Bossel's framework—are mutually intertwined and operationally integrated to create an "SD pyramid", differentiating specific analytical dimensions and, where possible, relevant indicators (Van Opstal and Hugé 2013). By offering specific examples of indicator classification according to Maslow's and Bossel's frameworks and their qualitative criteria, this system facilitates an examination of how various social, economic, and environmental complexities contribute to SD from an individual perspective (Peet 2004; Eustachio et al. 2019). The intensity and spatial trajectory of changes in the selected indicators, along with their placement within the pyramid, represent key aspects warranting continuous assessment (van Niekerk 2020). Furthermore, this approach enriches traditional, objective methods, establishing a conceptual link between an objective, aggregated evaluation of SD (i.e., using quantitative indicators) and a more subjective, disaggregated perspective focused on individual needs and qualitative indicators (van Zanten and van Tulder 2021).

More specifically, integrating Maslow's and Bossel's frameworks into a unified classification system of SDGs and SDIs, approached from the perspective of "human needs" (i.e., a purely individualistic perspective), helps to identify (i) research areas that lack comprehensive SDIs, (ii) significant gaps or partial shortages in pertinent information, and (iii) a set of essential indicators that condense necessary information into unique measures of SD. The findings of this approach aim to strengthen a quali-quantitative assessment of the subjective dimension of SD and the underlying data necessary for such statistical monitoring and reporting.

Improvements in research design should, for instance, facilitate a targeted comparison across regions and countries, potentially delineating the socio-environmental distinctiveness of diverse territorial contexts, a foundation for understanding the intrinsic disparities in SD levels across territories. A notable aspect of our approach, however, lies in its capacity to address all facets of SD, including those typically challenging to examine from a subjective perspective. For instance, ecological quality—a crucial but often complex dimension of SD to assess (e.g., Maialetti et al. 2024a)—can be investigated subjectively alongside the interplay between specific socioeconomic attributes and quality of life. This approach enables a meaningful integration with a traditionally objective dimension of SD (i.e., the inherent characteristics of a given socioeconomic context) as well as a hybrid (objective–subjective) dimension, such as quality of life (Alaimo and Maggino 2020).

In this perspective, incorporating Maslow's theory emphasizes the essential role of the environment in achieving satisfactory levels of happiness, being closely tied to the fulfillment of basic human needs (Pimentel et al. 2024). Recognizing the existence and significance of this relationship in evaluating SD within a specific location allows for the conceptualization of an "SD" function based on relevant socioeconomic characteristics and the associated quality of life (Przybyłowski et al. 2022; Wojewódzka-Wiewiórska et al. 2019). This approach offers a framework for addressing the genuine needs of individuals, thereby supporting the attainment of a satisfactory quality of life within a given territorial context and under specific socioeconomic constraints (Rojas et al. 2023). The integration of mixed quali-quantitative indicators of SD is, thus, central to this methodology. Additionally, subjective approaches that focus on individual perspectives on SD may enhance the informational value of quantitative indicators by highlighting the dimensions more effectively assessed through personal judgment and subjective evaluations rather than through conventional statistical measures (Burford et al. 2013).

From a practical standpoint, this approach holds particular value in cases where official statistics remain limited, incomplete, or insufficient for translating SDGs into fully quantitative SDIs at the desired spatial resolution and temporal scale for meaningful diachronic comparisons (Caudill et al. 2024). In both advanced and emerging economies, it is recognized that while official statistics are relatively harmonized globally—at least for a core set of indicators—there remains a need for enhancement and further consolidation to quantitatively capture the full scope of phenomena and processes outlined in the 17 UN SDGs (Campbell et al. 2020). A subjective approach can offer valuable supplementary insights, enabling the collection of information that may not be readily obtained from official statistics alone (Peet 2004).

From a theoretical standpoint, distinguishing between the human system, support system, and natural system through Maslow's framework enables a clearer understanding of the interactions between societal components and the environment (Maximova et al. 2023). Relevant measures for each of these subsystems could support the continuous monitoring of SD within a given location while also identifying future challenges, thus promoting a holistic approach to sustainability (Eustachio et al. 2019). As outlined in Section 4, the 17 SDGs can be mapped across Maslow's hierarchical levels of human needs (Fonseca et al. 2020). This mapping, as illustrated in Table 2, reveals that all of Maslow's identified needs are also addressed by the SDGs (Rojas et al. 2023). Among these, physiological needs are the most represented, being associated with at least 11 targets. Esteem and safety needs are each cited in four instances, while self-realization, aesthetic, and transcendental needs appear twice each. Self-actualization needs, however, are only referenced once.

The approach outlined herein, operationalized in Table 2, indicates that certain needs—particularly those related to spiritual and transcendental aspects—are nearly absent in the current classification. This gap may warrant a more in-depth analysis of motivational needs and their influence on sustainability, as understanding human motivations is essential for formulating effective policies (Bandhu et al. 2024). Furthermore, this observation underscores the value of applying a general framework, such as Maslow's pyramid of individual needs, to identify potential conceptual gaps in the SDGs and their related indicators, especially considering that the SDGs aim for a holistic definition of SD (Custodio et al. 2023). Future studies should reinforce the empirical basis for the theoretical approach proposed in this research. Validating this framework with real data and normative indicators would be a promising research direction, enhancing its relevance to the SD field. Operational models, involving comprehensive SD indicator dashboards derived from a UN SDGs perspective and demonstrating practical classification applications, would reduce the speculative nature of this proposal and facilitate empirical case studies.

Analyzing the interaction between human needs and their immediate environments reveals both individual and community dynamics (Stern 1993). This study is based on the premise that human development and environmental quality are deeply interconnected, influencing sustainability outcomes (Punit and Singh 2023). Recognizing specific strengths and challenges within a given area helps align human needs with ecological requirements, thus enhancing planning, development, and social policies (Hoffmann 2022). Human well-being fundamentally relies on a healthy environment, which is essential for personal growth and quality of life (Betley et al. 2023). Accessible green spaces, clean water, and public services serve as foundational elements of collective welfare (Ramaswami 2020). Advancing this perspective calls for research exploring the relationship between quality of life and critical economic, social, and environmental indicators, with frameworks like Maslow's pyramid offering valuable insights. Simplifying SDG indicators into consolidated dashboards can facilitate effective monitoring and a balanced approach to local and global policy objectives, reflecting each region's unique needs (Horan 2020).

6. Conclusions

In pursuit of a more holistic and systematic approach to measuring SD from both objective and subjective perspectives, the "SD pyramid" proposed in this study offers a valuable framework for classifying indicators that comprehensively assess SD and highlight the interdependencies between individual human needs and broader SDGs. By mapping human needs onto the SDGs, this study demonstrates the intrinsic compatibility between fundamental human needs and SDIs. From a normative perspective, this interdisciplinary approach provides a fresh lens on SD by incorporating human needs on both individual and societal levels, which can be especially informative for decision makers at local and international levels, particularly in urban and environmental policy contexts. From a positive perspective, the proposed framework offers a detailed view of SD by linking it to the dimension of human needs as structured by Maslow's hierarchy and Bossel's classification system.

The findings underscore the critical role of human well-being as a cornerstone of SD, revealing that an effective sustainability strategy must accommodate various levels of human need while prioritizing ecological balance. Practical applications of this framework suggest pathways for policymakers to better address localized socio-environmental contexts and socioeconomic disparities. Additionally, by proposing a structured integration of objective and subjective indicators, this study advocates for a balanced approach to global sustainability metrics that can address the gaps in existing quantitative-only evaluations.

The proposed Maslow–Bossel framework can be effectively applied to real-world policies by guiding the design and evaluation of sustainable urban development programs. For instance, in urban resilience planning, the framework facilitates the alignment of human needs, such as safety and belonging, with the objectives of the SDGs. In practice, this approach can be employed to structure policies addressing affordable housing, public safety, and access to green spaces by integrating indicators that reflect both subjective well-being and objective environmental performance. For example, the framework can inform urban infrastructure projects by ensuring that the provision of clean water and sanitation (SDG 6), alongside sustainable cities and communities (SDG 11), also addresses the psychological and social needs of residents, such as their sense of security and community inclusion. This dual focus enhances the ability of policymakers to design interventions that are both practically viable and holistically aligned with sustainability principles. By embedding this integrative perspective into policy frameworks, stakeholders can ensure that development efforts are not only environmentally sustainable but also responsive to the nuanced needs of diverse populations.

To further operationalize the framework, policymakers could leverage its principles in real-world initiatives such as national sustainability strategies, regional urban planning policies, and global adaptation mechanisms like those recently discussed at COP29 in Baku, Azerbaijan. Specifically, aligning the Maslow–Bossel framework with the reporting requirements of, inter alia, the Nationally Determined Contributions and Biennial Transparency Reports could provide a structured method for tracking progress on adaptation and resilience. For example, incorporating subjective well-being indicators into adaptation strategies would enable a more inclusive approach that captures diverse socioeconomic contexts, particularly those of vulnerable populations, such as women and indigenous communities. Additionally, the proposed composite indicators could be utilized in participatory research settings to bridge the gap between global sustainability metrics and localized decision-making processes. By embedding these applications into existing policy frameworks, the Maslow–Bossel framework has the potential to drive both practical and transformative changes in sustainable development initiatives at multiple governance levels.

Future research should focus on validating this framework with empirical data across different regions, aiming to refine the indicators and enhance the interpretive power of the proposed "SD pyramid". As SD continues to evolve, frameworks that recognize the interplay between individual needs and systemic sustainability goals will be essential to achieving comprehensive and equitable progress on a global scale.

Integrating a basic classification of human needs, as proposed by Maslow, with the complexities of the SDGs—and further contextualizing this through Bossel's approach—illustrates how sustainability objectives align with various levels of the hierarchy of needs, particularly from physiological safety to self-realization. Reorganizing and expanding the academic discourse on SDIs to include, or at least complement, a subjective and individual perspective represents a particularly relevant contribution of this study to sustainability science.

This study ultimately provides a valuable roadmap for policymakers, researchers, and stakeholders striving to harmonize economic growth, ecological responsibility, and social equity within SD initiatives.

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References

Abrudan, Leonard-Călin, Mirabela-Constanța Matei, and Maria-Madela Abrudan. 2021. Towards Sustainable Finance: Conceptualizing Future Generations as Stakeholders. *Sustainability* 13: 13717. [CrossRef]

Ahmad, Munir, and Yiyun Wu. 2022. Combined Role of Green Productivity Growth, Economic Globalization, and Eco-Innovation in Achieving Ecological Sustainability for OECD Economies. *Journal of Environmental Management* 302: 113980. [CrossRef] [PubMed]

Aksoy, Fadime, and Nuran Bayram Arlı. 2020. Evaluation of Sustainable Happiness with Sustainable Development Goals: Structural Equation Model Approach. *Sustainable Development* 28: 385–92. [CrossRef]

Alaimo, Leonardo S., and Filomena Maggino. 2020. Sustainable Development Goals Indicators at Territorial Level: Conceptual and Methodological Issues—The Italian Perspective. *Social Indicators Research* 147: 383–419. [CrossRef]

Ali, Syed Mithun, Andrea Appolloni, Fausto Cavallaro, Idiano D'Adamo, Assunta Di Vaio, Francesco Ferella, Massimo Gastaldi, Muhammad Ikram, Nallapaneni Manoj Kumar, Michael Alan Martin, and et al. 2023. Development Goals towards Sustainability. *Sustainability* 15: 9443. [CrossRef]

Aliyu, Umar Shuaibu, Huseyin Ozdeser, Behiye Çavuşoğlu, and Mohammed A. M. Usman. 2021. Food Security Sustainability: A Synthesis of the Current Concepts and Empirical Approaches for Meeting SDGs. *Sustainability* 13: 11728. [CrossRef]

Alkire, Sabina, and Andy Sumner. 2013. Multidimensional Poverty and the Post-2015 MDGs. *Development* 56: 46–51. [CrossRef]

Alkire, Sabina, Usha Kanagaratnam, Ricardo Nogales, and Nicolai Suppa. 2022. Revising the Global Multidimensional Poverty Index: Empirical Insights and Robustness. *Review of Income and Wealth* 68: S347–S384. [CrossRef]

Allen, Cameron, Michael Reid, John Thwaites, Rod Glover, and Tahl Kestin. 2020. Assessing National Progress and Priorities for the Sustainable Development Goals (SDGs): Experience from Australia. *Sustainability Science* 15: 521–38. [CrossRef]

Alt, Kurt W., Ali Al-Ahmad, and Johan Peter Woelber. 2022. Nutrition and Health in Human Evolution–Past to Present. *Nutrients* 14: 3594. [CrossRef]

Atkinson, Joel, and Luisa Cools. 2017. Sustainability of Capture Fisheries and SDG 14: Life Below Water. *International Studies Review* 18: 23–50. [CrossRef]

Bagheri, Ali, and Peder Hjorth. 2007. Planning for Sustainable Development: A Paradigm Shift towards a Process-Based Approach. *Sustainable Development* 15: 83–96. [CrossRef]

Bali Swain, Ranjula, and Fan Yang-Wallentin. 2020. Achieving Sustainable Development Goals: Predicaments and Strategies. *International Journal of Sustainable Development & World Ecology* 27: 96–106. [CrossRef]

Bandhu, Din, M. Murali Mohan, Noel Anurag Prashanth Nittala, Pravin Jadhav, Alok Bhadauria, and Kuldeep K. Saxena. 2024. Theories of Motivation: A Comprehensive Analysis of Human Behavior Drivers. *Acta Psychologica* 244: 104177. [CrossRef] [PubMed]

Baranyi, Stephen, Yiagadeesen Samy, and Bianca Washuta. 2021. SDG16+ Implementation in Fragile and Conflict-Affected States: What Do the Data Tell Us Six Years into Agenda 2030? *Conflict, Security & Development* 21: 727–48. [CrossRef]

Barbier, Edward B., and Joanne C. Burgess. 2017. The Sustainable Development Goals and the Systems Approach to Sustainability. *Economics* 11: 20170028. [CrossRef]

Barbier, Edward B., and Joanne C. Burgess. 2019. Sustainable Development Goal Indicators: Analyzing Trade-Offs and Complementarities. *World Development* 122: 295–305. [CrossRef]

Barone, Giovanni, Annamaria Buonomano, Cesare Forzano, Giovanni Francesco Giuzio, and Adolfo Palombo. 2021. Supporting the Sustainable Energy Transition in the Canary Islands: Simulation and Optimization of Multiple Energy System Layouts and Economic Scenarios. *Frontiers in Sustainable Cities* 3: 685525. [CrossRef]

Belgacem, Wajdi, Konstadinos Mattas, George Arampatzis, and George Baourakis. 2021. Changing Dietary Behavior for Better Biodiversity Preservation: A Preliminary Study. *Nutrients* 13: 2076. [CrossRef]

Benson, Suzanne G., and Stephen P. Dundis. 2003. Understanding and Motivating Health Care Employees: Integrating Maslow's Hierarchy of Needs, Training and Technology. *Journal of Nursing Management* 11: 315–20. [CrossRef]

Betley, Erin C., Amanda Sigouin, Pua'ala Pascua, Samantha H. Cheng, Kenneth Iain MacDonald, Felicity Arengo, Yildiz Aumeeruddy-Thomas, Sophie Caillon, Marney E. Isaac, Stacy D. Jupiter, and et al. 2023. Assessing Human Well-being Constructs with Environmental and Equity Aspects: A Review of the Landscape. *People and Nature* 5: 1756–73. [CrossRef]

Bianconi, Fabio, Matteo Clemente, Marco Filippucci, and Luca Salvati. 2018. Regenerating Urban Spaces: A Brief Commentary on Green Infrastructures for Landscape Conservation. *TeMA-Journal of Land Use, Mobility and Environment* 11: 107–18. [CrossRef]

Bidarbakhtnia, Arman. 2020. Measuring Sustainable Development Goals (SDGs): An Inclusive Approach. *Global Policy* 11: 56–67. [CrossRef]

Bieszk-Stolorz, Beata, and Krzysztof Dmytrów. 2023. Decent Work and Economic Growth in EU Countries—Static and Dynamic Analyses of Sustainable Development Goal 8. *Sustainability* 15: 13327. [CrossRef]

Bishop, Ryan, Kristoffer Gansing, Jussi Parikka, and Elvia Wilk, eds. 2016. *Across and Beyond: A Transmediale Reader on Post-Digital Practices, Concepts, and Institutions*. Berlin: Sternberg Press. ISBN 3956792890.

Bonnet, Jean, Eva Coll-Martínez, and Patricia Renou-Maissant. 2021. Evaluating Sustainable Development by Composite Index: Evidence from French Departments. *Sustainability* 13: 761. [CrossRef]

Bossel, Hartmut. 1999. *Indicators for Sustainable Development: Theory, Method, Applications*. Winnipeg: International Institute for Sustainable Development. ISBN 9781895536133.

Bradley Guy, G., and Charles J. Kibert. 1998. Developing Indicators of Sustainability: US Experience. *Building Research & Information* 26: 39–45. [CrossRef]

Bridgman, Todd, Stephen Cummings, and John Ballard. 2019. Who Built Maslow's Pyramid? A History of the Creation of Management Studies' Most Famous Symbol and Its Implications for Management Education. *Academy of Management Learning & Education* 18: 81–98. [CrossRef]

Brulé, Gaël. 2022. Evaluation of Existing Indexes of Sustainable Well-Being and Propositions for Improvement. *Sustainability* 14: 1027. [CrossRef]

Bulmer, Elena, and Benito Yáñez-Araque. 2023. Tackling Climate Change through Multi-Stakeholder Partnerships: Promoting SDG 17 to Combat Climate Change. *Energies* 16: 3777. [CrossRef]

Burford, Gemma, Elona Hoover, Ismael Velasco, Svatava Janoušková, Alicia Jimenez, Georgia Piggot, Dimity Podger, and Marie Harder. 2013. Bringing the 'Missing Pillar' into Sustainable Development Goals: Towards Intersubjective Values-Based Indicators. *Sustainability* 5: 3035–59. [CrossRef]

Caballero, Paula. 2019. The SDGs: Changing How Development Is Understood. *Global Policy* 10: 138–40. [CrossRef]

Callenbach, Ernest. 2014. Sustainable Shrinkage: Envisioning a Smaller, Stronger Economy. In *Creating a Sustainable and Desirable Future*. Singapore: World Scientific, pp. 223–32. [CrossRef]

Campbell, J., J. Neuner, L. See, S. Fritz, D. Fraisl, J. Espey, and A. Kim. 2020. The Role of Combining National Official Statistics with Global Monitoring to Close the Data Gaps in the Environmental SDGs. *Statistical Journal of the IAOS* 36: 443–53. [CrossRef]

Cao, Huanhuan, Jinhu Jiang, Lih-Bin Oh, Hao Li, Xiuwu Liao, and Zhiwu Chen. 2013. A Maslow's Hierarchy of Needs Analysis of Social Networking Services Continuance. *Journal of Service Management* 24: 170–90. [CrossRef]

Cardenas, Juan Camilo. 2011. Social Norms and Behavior in the Local Commons as Seen Through the Lens of Field Experiments. *Environmental and Resource Economics* 48: 451–85. [CrossRef]

Carlsen, Lars, and Rainer Bruggemann. 2022. The 17 United Nations' Sustainable Development Goals: A Status by 2020. *International Journal of Sustainable Development & World Ecology* 29: 219–29. [CrossRef]

Caudill, Christy M., Peter L. Pulsifer, Romola V. Thumbadoo, and D. R. Fraser Taylor. 2024. Meeting the Challenges of the UN Sustainable Development Goals through Holistic Systems Thinking and Applied Geospatial Ethics. *ISPRS International Journal of Geo-Information* 13: 110. [CrossRef]

Cheshmehzangi, Ali, and Tong Zou. 2024. Literary Analysis of the Connection between Urban Innovations and Sustainable Development Goals (SDGs). *Sustainability* 16: 6405. [CrossRef]

Cibulka, Stefan, and Stefan Giljum. 2020. Towards a Comprehensive Framework of the Relationships between Resource Footprints, Quality of Life, and Economic Development. *Sustainability* 12: 4734. [CrossRef]

Cojocaru, Teodor Marian, George H. Ionescu, Daniela Firoiu, Laura Mariana Cismaș, Maria Daniela Oțil, and Ovidiu Toma. 2022. Reducing Inequalities within and among EU Countries—Assessing the Achievement of the 2030 Agenda for Sustainable Development Targets (SDG 10). *Sustainability* 14: 7706. [CrossRef]

Cortesi, Anna, Ioannis Vardopoulos, and Luca Salvati. 2022. A Partial Least Squares Analysis of the Perceived Impact of Sustainable Real Estate Design upon Wellbeing. *Urban Science* 6: 69. [CrossRef]

Costa, Joana, Diana Cancela, and João Reis. 2021. Neverland or Tomorrowland? Addressing (In)Compatibility among the SDG Pillars in Europe. *International Journal of Environmental Research and Public Health* 18: 11858. [CrossRef] [PubMed]

Costanza, Robert, Brendan Fisher, Saleem Ali, Caroline Beer, Lynne Bond, Roelof Boumans, Nicholas L. Danigelis, Jennifer Dickinson, Carolyn Elliott, Joshua Farley, and et al. 2007. Quality of Life: An Approach Integrating Opportunities, Human Needs, and Subjective Well-Being. *Ecological Economics* 61: 267–76. [CrossRef]

Cruz, Sofia Alexandra. 2023. SDG 17 and Global Partnership for Sustainable Development: Unraveling the Rhetoric of Collaboration. *Frontiers in Environmental Science* 11: 1155828. [CrossRef]

Custodio, Henry M., Michalis Hadjikakou, and Brett A. Bryan. 2023. A Review of Socioeconomic Indicators of Sustainability and Wellbeing Building on the Social Foundations Framework. *Ecological Economics* 203: 107608. [CrossRef]

Dada, Shakila, Karen Wylie, Julie Marshall, David Rochus, and Josephine Ohenewa Bampoe. 2023. The Importance of SDG 17 and Equitable Partnerships in Maximising Participation of Persons with Communication Disabilities and Their Families. *International Journal of Speech-Language Pathology* 25: 183–87. [CrossRef] [PubMed]

Delli Paoli, Angela, and Felice Addeo. 2019. Assessing SDGs: A Methodology to Measure Sustainability. *Athens Journal of Social Sciences* 6: 229–50. [CrossRef]

Demeterova, Barbara, Tatjana Fischer, and Jürgen Schmude. 2020. The Right to Not Catch Up—Transitioning European Territorial Cohesion towards Spatial Justice for Sustainability. *Sustainability* 12: 4797. [CrossRef]

Díaz-López, Carmen, Cathaysa Martín-Blanco, Juan Jesús De la Torre Bayo, Benito Rubio-Rivera, and Montserrat Zamorano. 2021. Analyzing the Scientific Evolution of the Sustainable Development Goals. *Applied Sciences* 11: 8286. [CrossRef]

Doukas, Yannis E., and Ioannis Vardopoulos. 2023. A Pathway to Sustainable Policy: Unraveling the Interplay of Socio-Cultural Factors, Local Contexts, and Institutional Dynamics in Food Waste Reduction. In *3rd International Conference RETASTE: Rethink Food Resources, Losses, and Waste, 27–29 September 2023, Athens, Greece. Book of Abstracts*. Edited by Thrassyvoulos Manios, Katia Lasaridi, Konstadinos Abeliotis and Ioannis Daliakopoulos. Heraklion: Hellenic Mediterranean University, pp. 275–77. ISBN 9786188477476.

Doukas, Yannis E., Luca Salvati, and Ioannis Vardopoulos. 2023. Unraveling the European Agricultural Policy Sustainable Development Trajectory. *Land* 12: 1749. [CrossRef]

Doukas, Yannis E., Napoleon Maravegias, and George Andreou, eds. 2022. *Η Χωρική Διάσταση Της Ευρωπαϊκής Ολοκλήρωσης: Σύγκλιση ή Απόκλιση*. Athens: Dionicos. ISBN 9786185665036.

Dulume, Wekgari. 2019. Linking the SDGS with Human Rights: Opportunities and Challenges of Promoting Goal 17. *Journal of Sustainable Development Law and Policy (The)* 10: 56–72. [CrossRef]

"Education". 1964. Education: A Vital Responsibility. *Simulation* 2: 13. [CrossRef]

El Chami, Daniel. 2021. Sustainable Development and Economic Growth: A Reality or an Oxymoron? *European Scientific Journal ESJ* 17: 41. [CrossRef]

Eliades, Filippos, Maria K. Doula, Iliana Papamichael, Ioannis Vardopoulos, Irene Voukkali, and Antonis A. Zorpas. 2022. Carving out a Niche in the Sustainability Confluence for Environmental Education Centers in Cyprus and Greece. *Sustainability* 14: 8368. [CrossRef]

Eustachio, João Henrique Paulino Pires, Adriana Cristina Ferreira Caldana, Lara Bartocci Liboni, and Dante Pinheiro Martinelli. 2019. Systemic Indicator of Sustainable Development: Proposal and Application of a Framework. *Journal of Cleaner Production* 241: 118383. [CrossRef]

Everard, Mark, Mark S. Reed, and Jasper O. Kenter. 2016. The Ripple Effect: Institutionalising pro-Environmental Values to Shift Societal Norms and Behaviours. *Ecosystem Services* 21: 230–40. [CrossRef]

Ferrara, Agostino, Luca Salvati, Adele Sateriano, and Angelo Nolè. 2012. Performance Evaluation and Cost Assessment of a Key Indicator System to Monitor Desertification Vulnerability. *Ecological Indicators* 23: 123–29. [CrossRef]

Firoiu, Daniela, George H. Ionescu, Anca Băndoi, Nicoleta Mihaela Florea, and Elena Jianu. 2019. Achieving Sustainable Development Goals (SDG): Implementation of the 2030 Agenda in Romania. *Sustainability* 11: 2156. [CrossRef]

Fonseca, Luis Miguel, José Pedro Domingues, and Alina Mihaela Dima. 2020. Mapping the Sustainable Development Goals Relationships. *Sustainability* 12: 3359. [CrossRef]

Fonseca, Salvador, António Moreira, and Jorge Mota. 2024. Factors Influencing Sustainable Poverty Reduction: A Systematic Review of the Literature with a Microfinance Perspective. *Journal of Risk and Financial Management* 17: 309. [CrossRef]
Forsyth, Tim. 2013. Community-based Adaptation: A Review of Past and Future Challenges. *WIREs Climate Change* 4: 439–46. [CrossRef]
Fotopoulou, Eleni, Ioanna Mandilara, Anastasios Zafeiropoulos, Chrysi Laspidou, Giannis Adamos, Phoebe Koundouri, and Symeon Papavassiliou. 2022. SustainGraph: A Knowledge Graph for Tracking the Progress and the Interlinking among the Sustainable Development Goals' Targets. *Frontiers in Environmental Science* 10: 1003599. [CrossRef]
Fritz, Martin, and Max Koch. 2014. Potentials for Prosperity without Growth: Ecological Sustainability, Social Inclusion and the Quality of Life in 38 Countries. *Ecological Economics* 108: 191–99. [CrossRef]
Frontistis, Zacharias. 2021. New Trends in Environmental Catalytic Technologies for Water Remediation. *Water* 13: 571. [CrossRef]
Fry, Deborah A., and Stuart P. Elliott. 2017. Understanding the Linkages between Violence against Women and Violence against Children. *The Lancet Global Health* 5: e472–e473. [CrossRef] [PubMed]
Fu, Bojie, Junze Zhang, Shuai Wang, and Wenwu Zhao. 2020. Classification–Coordination–Collaboration: A Systems Approach for Advancing Sustainable Development Goals. *National Science Review* 7: 838–40. [CrossRef]
Galabada, Jalini Kaushalya. 2022. Towards the Sustainable Development Goal of Zero Hunger: What Role Do Institutions Play? *Sustainability* 14: 4598. [CrossRef]
Galindo-Martín, Miguel-Angel, María-Soledad Castaño-Martínez, and María-Teresa Méndez-Picazo. 2020. The Relationship between Green Innovation, Social Entrepreneurship, and Sustainable Development. *Sustainability* 12: 4467. [CrossRef]
García-Moreno, Claudia, and Avni Amin. 2016. The Sustainable Development Goals, Violence and Women's and Children's Health. *Bulletin of the World Health Organization* 94: 396–97. [CrossRef]
Ghatak, Sanchita, and Surabhi Singh. 2019. Examining Maslow's Hierarchy Need Theory in the Social Media Adoption. *FIIB Business Review* 8: 292–302. [CrossRef]
Ghislandi, Simone, Warren C. Sanderson, and Sergei Scherbov. 2019. A Simple Measure of Human Development: The Human Life Indicator. *Population and Development Review* 45: 219–33. [CrossRef]
Giangrande, Naresh, Rehema M. White, May East, Ross Jackson, Tim Clarke, Michel Saloff Coste, and Gil Penha-Lopes. 2019. A Competency Framework to Assess and Activate Education for Sustainable Development: Addressing the UN Sustainable Development Goals 4.7 Challenge. *Sustainability* 11: 2832. [CrossRef]
Gourgiotis, Anestis, Dionisia Koutsi, Vasiliki Krommyda, and Anastasia Stratigea. 2024. Spatial and Developmental Policy Directions Affecting Marine Spatial Planning in the Northern Aegean Sea, Greece. *Oceans* 5: 522–46. [CrossRef]
Grimani, Aikaterini, Emmanuel Aboagye, and Lydia Kwak. 2019. The Effectiveness of Workplace Nutrition and Physical Activity Interventions in Improving Productivity, Work Performance and Workability: A Systematic Review. *BMC Public Health* 19: 1676. [CrossRef] [PubMed]
Griskevicius, Vladas, Robert B. Cialdini, and Douglas T. Kenrick. 2006. Peacocks, Picasso, and Parental Investment: The Effects of Romantic Motives on Creativity. *Journal of Personality and Social Psychology* 91: 63–76. [CrossRef]
Guo, Huadong, Dong Liang, Zhongchang Sun, Fang Chen, Xinyuan Wang, Junsheng Li, Li Zhu, Jinhu Bian, Yanqiang Wei, Lei Huang, and et al. 2022. Measuring and Evaluating SDG Indicators with Big Earth Data. *Science Bulletin* 67: 1792–801. [CrossRef] [PubMed]
Gusmão Caiado, Rodrigo Goyannes, Walter Leal Filho, Osvaldo Luiz Gonçalves Quelhas, Daniel Luiz de Mattos Nascimento, and Lucas Veigas Ávila. 2018. A Literature-Based Review on Potentials and Constraints in the Implementation of the Sustainable Development Goals. *Journal of Cleaner Production* 198: 1276–88. [CrossRef]
Halbac-Cotoara-Zamfir, Rares, Daniela Smiraglia, Giovanni Quaranta, Rosanna Salvia, Luca Salvati, and Antonio Giménez-Morera. 2020. Land Degradation and Mitigation Policies in the Mediterranean Region: A Brief Commentary. *Sustainability* 12: 8313. [CrossRef]
Hariram, N. P., K. B. Mekha, Vipinraj Suganthan, and K. Sudhakar. 2023. Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability. *Sustainability* 15: 10682. [CrossRef]
Harvard, Phillip Sinclair. 2010. Maslow, Mazes, Minotaurs; Updating Employee Needs and Behavior Patterns in a Knowledge-Based Global Economy. *Journal of the Knowledge Economy* 1: 117–27. [CrossRef]
Hák, Tomáš, Svatava Janoušková, and Bedřich Moldan. 2016. Sustainable Development Goals: A Need for Relevant Indicators. *Ecological Indicators* 60: 565–73. [CrossRef]
Heckman, James, Hidehiko Ichimura, Jeffrey Smith, and Petra Todd. 1998. Characterizing Selection Bias Using Experimental Data. *Econometrica* 66: 1017. [CrossRef]
Hjorth, Peder, and Ali Bagheri. 2006. Navigating towards Sustainable Development: A System Dynamics Approach. *Futures* 38: 74–92. [CrossRef]
Hoffmann, Samuel. 2022. Challenges and Opportunities of Area-Based Conservation in Reaching Biodiversity and Sustainability Goals. *Biodiversity and Conservation* 31: 325–52. [CrossRef]
Horan, David. 2020. Enabling Integrated Policymaking with the Sustainable Development Goals: An Application to Ireland. *Sustainability* 12: 7800. [CrossRef]
Horton, Richard. 2015. Offline: Gender Equality—The Neglected SDG for Health. *The Lancet* 386: 1928. [CrossRef] [PubMed]
Huan, Yizhong, Tao Liang, Haitao Li, and Chaosheng Zhang. 2021. A Systematic Method for Assessing Progress of Achieving Sustainable Development Goals: A Case Study of 15 Countries. *Science of The Total Environment* 752: 141875. [CrossRef]

Huang, Yanfang, Fengying Nie, and Xiangping Jia. 2023. Forty Years after Poverty Reduction in China: The Role of Women's Empowerment in Enhancing Food Security and Diet Diversity. *Nutrients* 15: 2761. [CrossRef]
Hueting, Roefie, and Lucas Reijnders. 2004. Broad Sustainability Contra Sustainability: The Proper Construction of Sustainability Indicators. *Ecological Economics* 50: 249–60. [CrossRef]
Inglezakis, Vassilis, and Antonis A. Zorpas. 2014. Environmental Indicators. In *Sustainability Behind Sustainability*. Edited by Antonis A. Zorpas. Hauppauge: Nova Science Publishers, pp. 17–33. ISBN 9781633215955.
Jacob, Arun. 2017. Mind the Gap: Analyzing the Impact of Data Gap in Millennium Development Goals' (MDGs) Indicators on the Progress toward MDGs. *World Development* 93: 260–78. [CrossRef]
Jolibert, Catherine, Jouni Paavola, and Felix Rauschmayer. 2014. Addressing Needs in the Search for Sustainable Development: A Proposal for Needs-Based Scenario Building. *Environmental Values* 23: 29–50. [CrossRef]
Jovanović, Violeta, Sunčica Stanković, and Vesna Krstić. 2023. Environmental, Social and Economic Sustainability in Mining Companies as a Result of the Interaction between Knowledge Management and Green Innovation—The SEM Approach. *Sustainability* 15: 12122. [CrossRef]
Kapsalis, Vasilis C., Grigorios L. Kyriakopoulos, and Konstantinos G. Aravossis. 2019. Investigation of Ecosystem Services and Circular Economy Interactions under an Inter-Organizational Framework. *Energies* 12: 1734. [CrossRef]
Kavouras, Sotirios, Ioannis Vardopoulos, Roido Mitoula, Antonis A. Zorpas, and Panagiotis Kaldis. 2022. Occupational Health and Safety Scope Significance in Achieving Sustainability. *Sustainability* 14: 2424. [CrossRef]
Kenrick, Douglas T., Vladas Griskevicius, Steven L. Neuberg, and Mark Schaller. 2010. Renovating the Pyramid of Needs. *Perspectives on Psychological Science* 5: 292–314. [CrossRef] [PubMed]
Khan, Parvez Alam, Satirenjit Kaur Johl, Shakeb Akhtar, Mohammad Asif, Anas A. Salameh, and Thavamaran Kanesan. 2022. Open Innovation of Institutional Investors and Higher Education System in Creating Open Approach for SDG-4 Quality Education: A Conceptual Review. *Journal of Open Innovation: Technology, Market, and Complexity* 8: 49. [CrossRef]
Khraisha, Tamer. 2020. Complex Economic Problems and Fitness Landscapes: Assessment and Methodological Perspectives. *Structural Change and Economic Dynamics* 52: 390–407. [CrossRef]
King, Loren A. 1998. Economic Growth and Basic Human Needs. *International Studies Quarterly* 42: 385–400. [CrossRef]
Kisel'áková, Dana, Beáta Šofranková, Miroslav Gombár, Veronika Čabinová, and Erika Onuferová. 2019. Competitiveness and Its Impact on Sustainability, Business Environment, and Human Development of EU (28) Countries in Terms of Global Multi-Criteria Indices. *Sustainability* 11: 3365. [CrossRef]
Klaassen, Ger A. J., and Johannes B. Opschoor. 1991. Economics of Sustainability or the Sustainability of Economics: Different Paradigms. *Ecological Economics* 4: 93–115. [CrossRef]
Klopp, Jacqueline M., and Danielle L. Petretta. 2017. The Urban Sustainable Development Goal: Indicators, Complexity and the Politics of Measuring Cities. *Cities* 63: 92–97. [CrossRef]
Koliaki, Chrysi C., Nicholas L. Katsilambros, and Charilaos Dimosthenopoulos. 2024. The Mediterranean Diet in the Era of Climate Change: A Reference Diet for Human and Planetary Health. *Climate* 12: 136. [CrossRef]
Koltko-Rivera, Mark E. 2006. Rediscovering the Later Version of Maslow's Hierarchy of Needs: Self-Transcendence and Opportunities for Theory, Research, and Unification. *Review of General Psychology* 10: 302–17. [CrossRef]
Kougea, Eva, and Phoebe Koundouri. 2011. Air Quality Degradation: Can Economics Help in Measuring Its Welfare Effects? A Review of Economic Valuation Studies. In *Indoor and Outdoor Air Pollution*. London: InTech. [CrossRef]
Koundouri, Phoebe, Angelos Alamanos, Angelos Plataniotis, Charis Stavridis, Konstantinos Perifanos, and Stathis Devves. 2024. Assessing the Sustainability of the European Green Deal and Its Interlin Kages with the SDGs. *Npj Climate Action* 3: 23. [CrossRef]
Krank, Sabrina, Holger Wallbaum, and Adrienne Grêt-Regamey. 2013. Perceived Contribution of Indicator Systems to Sustainable Development in Developing Countries. *Sustainable Development* 21: 18–29. [CrossRef]
Kritikou, Theodora, Dimosthenis Panagiotakos, Konstantinos Abeliotis, and Katia Lasaridi. 2021. Investigating the Determinants of Greek Households Food Waste Prevention Behaviour. *Sustainability* 13: 11451. [CrossRef]
Kubiszewski, Ida, Kenneth Mulder, Diane Jarvis, and Robert Costanza. 2022. Toward Better Measurement of Sustainable Development and Wellbeing: A Small Number of SDG Indicators Reliably Predict Life Satisfaction. *Sustainable Development* 30: 139–48. [CrossRef]
Kuhlman, Tom, and John Farrington. 2010. What Is Sustainability? *Sustainability* 2: 3436–48. [CrossRef]
Kynčlová, Petra, Shyam Upadhyaya, and Thomas Nice. 2020. Composite Index as a Measure on Achieving Sustainable Development Goal 9 (SDG-9) Industry-Related Targets: The SDG-9 Index. *Applied Energy* 265: 114755. [CrossRef]
Lancker, Elly, and Peter Nijkamp. 2000. A Policy Scenario Analysis of Sustainable Agricultural Development Options: A Case Study for Nepal. *Impact Assessment and Project Appraisal* 18: 111–24. [CrossRef]
Land, Kenneth C. 2015. The Human Development Index: Objective Approaches (2). In *Global Handbook of Quality of Life*. Dordrecht: Springer, pp. 133–57. [CrossRef]
Lans Bovenberg, A., and Sjak Smulders. 1995. Environmental Quality and Pollution-Augmenting Technological Change in a Two-Sector Endogenous Growth Model. *Journal of Public Economics* 57: 369–91. [CrossRef]
Lehtonen, Markku. 2004. The Environmental–Social Interface of Sustainable Development: Capabilities, Social Capital, Institutions. *Ecological Economics* 49: 199–214. [CrossRef]

Li, Zhilin, Xinyu Gong, Jun Chen, Jon Mills, Songnian Li, Zhu Xu, Peng Ti, and Hao Wu. 2020. Functional Requirements of Systems for Visualization of Sustainable Development Goal (SDG) Indicators. *Journal of Geovisualization and Spatial Analysis* 4: 5. [CrossRef]
Liu, Gengyuan, Mark Brown, and Marco Casazza. 2017. Enhancing the Sustainability Narrative through a Deeper Understanding of Sustainable Development Indicators. *Sustainability* 9: 1078. [CrossRef]
Lo-Iacono-Ferreira, Vanesa G., Ana Garcia-Bernabeu, Adolfo Hilario-Caballero, and Juan Torregrosa-López. 2022. Measuring Urban Sustainability Performance through Composite Indicators for Spanish Cities. *Journal of Cleaner Production* 359: 131982. [CrossRef]
Loizia, Pantelitsa, Irene Voukkali, Antonis A. Zorpas, Jose Navarro Pedreño, Georgia Chatziparaskeva, Vassilis J. Inglezakis, Ioannis Vardopoulos, and Maria Doula. 2021. Measuring the Level of Environmental Performance in Insular Areas, through Key Performed Indicators, in the Framework of Waste Strategy Development. *Science of The Total Environment* 753: 141974. [CrossRef]
Lomazzi, Marta, Bettina Borisch, and Ulrich Laaser. 2014. The Millennium Development Goals: Experiences, Achievements and What's Next. *Global Health Action* 7: 23695. [CrossRef]
Luan, Wenfei, Ling Lu, Xin Li, and Chunfeng Ma. 2017. Weight Determination of Sustainable Development Indicators Using a Global Sensitivity Analysis Method. *Sustainability* 9: 303. [CrossRef]
Lyytimäki, Jari, Hanna Salo, Robert Lepenies, Leonie Büttner, and Jyri Mustajoki. 2020. Risks of Producing and Using Indicators of Sustainable Development Goals. *Sustainable Development* 28: 1528–38. [CrossRef]
Maialetti, Marco, Luca Salvati, and Francesco Maria Chelli. 2024a. Sustainable Development, Territorial Disparities in Land Resources, and Soil Degradation: A Multi-Temporal Approach. *Resources* 13: 125. [CrossRef]
Maialetti, Marco, Matteo Clemente, Kostas Rontos, Donato Scarpitta, Alessandra Stefanoni, Fabrizio Rossi, Adele Sateriano, and Luca Salvati. 2024. Climate-Driven vs Human-Driven Land Degradation? The Role of Urbanization and Agricultural Intensification in Italy, 1960–2030. *Sustainability* 16: 8938. [CrossRef]
Maialetti, Marco, Rares Halbac-Cotoara-Zamfir, Ioannis Vardopoulos, and Luca Salvat. 2024c. Early Desertification Risk in Advanced Economies: Summarizing Past, Present, and Future Trends in Italy. *Earth* 5: 690–706. [CrossRef]
Martínez-Córdoba, Pedro-José, Nicola Raimo, Filippo Vitolla, and Bernardino Benito. 2020. Achieving Sustainable Development Goals. Efficiency in the Spanish Clean Water and Sanitation Sector. *Sustainability* 12: 3015. [CrossRef]
Maslow, Abraham Harold. 1943. A Theory of Human Motivation. *Psychological Review* 50: 370–96. [CrossRef]
Mathes, Eugene W. 1981. Maslow's Hierarchy of Needs as a Guide for Living. *Journal of Humanistic Psychology* 21: 69–72. [CrossRef]
Mațcu-Zaharia, Mara, Ioana Alexandra Horodnic, Colin C. Williams, and George Cristian Nistor. 2024. Self-Employed Workers and the Achievement of the 2030 Agenda for Sustainable Development: An Overview of Their Social Benefit Entitlements across 31 European Countries. *Sustainability* 16: 2625. [CrossRef]
Maximova, Svetlana G., Roman I. Raikin, Alexander A. Chibilev, and Marina M. Silantyeva, eds. 2023. *Advances in Natural, Human-Made, and Coupled Human-Natural Systems Research*. Lecture Notes in Networks and Systems. Cham: Springer International Publishing, vol. 252, ISBN 978-3-030-78104-0. [CrossRef]
McArthur, John W., and Krista Rasmussen. 2019. Classifying Sustainable Development Goal Trajectories: A Country-Level Methodology for Identifying Which Issues and People Are Getting Left Behind. *World Development* 123: 104608. [CrossRef]
Mehmetaj, Nevila, and Nevila Xhindi. 2022. Public Expenses in Education and Youth Unemployment Rates—A Vector Error Correction Model Approach. *Economies* 10: 293. [CrossRef]
Mikuła, Aneta, Małgorzata Raczkowska, and Monika Utzig. 2024. Implementation of Sustainable Development Goal 3: Good Health and Well-Being in European Union Countries in the Context of the COVID-19 Pandemic. *Sustainability* 16: 7921. [CrossRef]
Mindrinos, L., and P. Panagiotopoulos. 2023. Measuring Sustainable Development: A Weighting Approach to Sustainable Development Indicators. *International Journal of Multidisciplinary Research and Analysis* 6: 4510–20. [CrossRef]
Montag, Christian, Cornelia Sindermann, David Lester, and Kenneth L. Davis. 2020. Linking Individual Differences in Satisfaction with Each of Maslow's Needs to the Big Five Personality Traits and Panksepp's Primary Emotional Systems. *Heliyon* 6: e04325. [CrossRef]
Mouratidis, Kostas. 2021. Urban Planning and Quality of Life: A Review of Pathways Linking the Built Environment to Subjective Well-Being. *Cities* 115: 103229. [CrossRef]
Nagy-Pénzes, Gabriella, Ferenc Vincze, and Éva Bíró. 2020. Contributing Factors in Adolescents' Mental Well-Being—The Role of Socioeconomic Status, Social Support, and Health Behavior. *Sustainability* 12: 9597. [CrossRef]
Nickayin, Samaneh Sadat, Aubrey Jahelka, Shuwen Ye, Francesca Perrone, and Luca Salvati. 2023. Planning for Just Cities with Nature-Based Solutions: Sustainability and Socio-Environmental Inequalities in San José de Chamanga, Ecuador. *Land* 12: 604. [CrossRef]
Nickayin, Samaneh Sadat, Francesco Chelli, Rosario Turco, Bogdana Nosova, Chara Vavoura, and Luca Salvati. 2022. Economic Downturns, Urban Growth and Suburban Fertility in a Mediterranean Context. *Economies* 10: 252. [CrossRef]
Nilsson, Annika E., and Joan Nymand Larsen. 2020. Making Regional Sense of Global Sustainable Development Indicators for the Arctic. *Sustainability* 12: 1027. [CrossRef]
North, Douglass C. 1955. Location Theory and Regional Economic Growth. *Journal of Political Economy* 63: 243–58. [CrossRef]
Ostrom, Elinor. 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science* 325: 419–22. [CrossRef]
Panagiotopoulos, P., R. Mitoula, E. Georgitsoyanni, and E. Theodoropoulou. 2022. The Contribution of Sports Tourism to Sustainable Development Based on Sustainable Development Indicators—The Case of Greece. *International Journal of Multidisciplinary Research and Analysis* 5: 1666. [CrossRef]

Pappas, Georgios, Iliana Papamichael, A. A. Zorpas, Joshua E. Siegel, Jacob Rutkowski, and Konstantinos Politopoulos. 2021. Modelling Key Performance Indicators in a Gamified Waste Management Tool. *Modelling* 3: 27–53. [CrossRef]
Paprotny, Dominik. 2021. Convergence Between Developed and Developing Countries: A Centennial Perspective. *Social Indicators Research* 153: 193–225. [CrossRef]
Peet, John. 2004. Shaping the Future: Indicators of Need in the Third Millennium. *International Journal of Environment and Sustainable Development* 3: 353. [CrossRef]
Perchinunno, Paola, Lucia Mongelli, and Francesco Rotondo. 2020. A Multidimensional Approach for the Identification of Environmental and Health Wellness Territories. *Ecological Indicators* 110: 105911. [CrossRef]
Perry, George L. W., Sarah J. Richardson, Niki Harré, Dave Hodges, Phil O'B. Lyver, Fleur J. F. Maseyk, Riki Taylor, Jacqui H. Todd, Jason M. Tylianakis, Johanna Yletyinen, and et al. 2021. Evaluating the Role of Social Norms in Fostering Pro-Environmental Behaviors. *Frontiers in Environmental Science* 9: 620125. [CrossRef]
Pérez-Peña, María del Carmen, Mercedes Jiménez-García, Jose Ruiz-Chico, and Antonio Rafael Peña-Sánchez. 2021. Analysis of Research on the SDGs: The Relationship between Climate Change, Poverty and Inequality. *Applied Sciences* 11: 8947. [CrossRef]
Pimentel, Anna Karolina Osório, Luciana Aparecida Farias, Cristina Rossi Nakayama, Claudio Benedito Baptista Leite, Carla Grigoletto Duarte, and Luiz Omir de Cerqueira Leite. 2024. Maslow and the Environment: Integrating the Social Representation and the Theory of Needs. *Ambiente & Sociedade* 27: e00147. [CrossRef]
Pissourios, Ioannis A. 2013. An Interdisciplinary Study on Indicators: A Comparative Review of Quality-of-Life, Macroeconomic, Environmental, Welfare and Sustainability Indicators. *Ecological Indicators* 34: 420–27. [CrossRef]
Pokorný, Jan, and Alena Palacká. 2023. Well-Being as a Prerequisite for Sustainability on a Macroeconomic Scale? Case of V4 Countries. *Quality Innovation Prosperity* 27: 141–53. [CrossRef]
Przybyłowski, Adam, Agnieszka Kałaska, and Piotr Przybyłowski. 2022. Quest for a Tool Measuring Urban Quality of Life: ISO 37120 Standard Sustainable Development Indicators. *Energies* 15: 2841. [CrossRef]
Punit, Nitin, and Rajender Singh. 2023. A Statistical Analysis of Human and Environmental Indicators to Measure Development Process: A Case Study. *International Journal of Geography, Geology and Environment* 5: 168–76. [CrossRef]
Purvis, Ben, Yong Mao, and Darren Robinson. 2019. Three Pillars of Sustainability: In Search of Conceptual Origins. *Sustainability Science* 14: 681–95. [CrossRef]
Ramaswami, Anu. 2020. Unpacking the Urban Infrastructure Nexus with Environment, Health, Livability, Well-Being, and Equity. *One Earth* 2: 120–24. [CrossRef]
Ramos, Tomás B. 2019. Sustainability Assessment: Exploring the Frontiers and Paradigms of Indicator Approaches. *Sustainability* 11: 824. [CrossRef]
Reed, Mark, Evan D. G. Fraser, Stephen Morse, and Andrew J. Dougill. 2005. Integrating Methods for Developing Sustainability Indicators to Facilitate Learning and Action. *Ecology and Society* 10: resp3. [CrossRef]
Repetti, Rena L. 1987. Individual and Common Components of the Social Environment at Work and Psychological Well-Being. *Journal of Personality and Social Psychology* 52: 710–20. [CrossRef]
Ribeiro Hoffmann, Andrea, Paula Sandrin, and Yannis E. Doukas, eds. 2024. *Climate Change in Regional Perspective. European Union and Latin American Initiatives, Challenges, and Solutions*. Cham: United Nations University Series on Regionalism, Cham: Springer Nature, vol. 27, ISBN 9783031493287. [CrossRef]
Ricciolini, Elene, Lucia Rocchi, Matteo Cardinali, Luisa Paolotti, Francisco Ruiz, Jose M. Cabello, and Antonio Boggia. 2022. Assessing Progress Towards SDGs Implementation Using Multiple Reference Point Based Multicriteria Methods: The Case Study of the European Countries. *Social Indicators Research* 162: 1233–60. [CrossRef] [PubMed]
Rojas, Mariano, Alfonso Méndez, and Karen Watkins-Fassler. 2023. The Hierarchy of Needs Empirical Examination of Maslow's Theory and Lessons for Development. *World Development* 165: 106185. [CrossRef]
Rosati, Francesco, and Lourenço G. D. Faria. 2019. Addressing the SDGs in Sustainability Reports: The Relationship with Institutional Factors. *Journal of Cleaner Production* 215: 1312–26. [CrossRef]
Sachs, Jeffrey D. 2012. From Millennium Development Goals to Sustainable Development Goals. *The Lancet* 379: 2206–11. [CrossRef]
Sachs, Jeffrey D., and John W. McArthur. 2005. The Millennium Project: A Plan for Meeting the Millennium Development Goals. *The Lancet* 365: 347–53. [CrossRef]
Sachs, Jeffrey D., Guido Schmidt-Traub, Mariana Mazzucato, Dirk Messner, Nebojsa Nakicenovic, and Johan Rockström. 2019. Six Transformations to Achieve the Sustainable Development Goals. *Nature Sustainability* 2: 805–14. [CrossRef]
Salvati, Luca, and Marco Zitti. 2009. Substitutability and Weighting of Ecological and Economic Indicators: Exploring the Importance of Various Components of a Synthetic Index. *Ecological Economics* 68: 1093–99. [CrossRef]
Salvati, Luca, and Margherita Carlucci. 2014. A Composite Index of Sustainable Development at the Local Scale: Italy as a Case Study. *Ecological Indicators* 43: 162–71. [CrossRef]
Salvati, Luca, Carlotta Ferrara, and Piermaria Corona. 2015. Indirect Validation of the Environmental Sensitive Area Index Using Soil Degradation Indicators: A Country-Scale Approach. *Ecological Indicators* 57: 360–65. [CrossRef]
Salvati, Luca, Marco Zitti, and Adele Sateriano. 2013. Changes in City Vertical Profile as an Indicator of Sprawl: Evidence from a Mediterranean Urban Region. *Habitat International* 38: 119–25. [CrossRef]
Salvati, Luca, Marco Zitti, and Tomaso Ceccarelli. 2008. Integrating Economic and Environmental Indicators in the Assessment of Desertification Risk: A Case Study. *Applied Ecology and Environmental Research* 6: 129–38. [CrossRef]

Salvati, Luca, Margherita Carlucci, Pere Serra, and Ilaria Zambon. 2019. Demographic Transitions and Socioeconomic Development in Italy, 1862–2009: A Brief Overview. *Sustainability* 11: 242. [CrossRef]

Sardianou, Eleni, Vasilis Nikou, and Ioannis Kostakis. 2023. Harmonizing Sustainability Goals: Empirical Insights into Climate Change Mitigation and Circular Economy Strategies in Selected European Countries with SDG13 Framework. *Sustainability* 16: 296. [CrossRef]

Sarvajayakesavalu, Suriyanarayanan. 2015. Addressing Challenges of Developing Countries in Implementing Five Priorities for Sustainable Development Goals. *Ecosystem Health and Sustainability* 1: 1–4. [CrossRef]

Sateriano, Adele, Alessia D'Agata, and Ioannis Vardopoulos, eds. 2024. *Socio-Enviromental Change: The Path Toward Sustainability*. Hauppauge: Nova Science Publishers. ISBN 9798895301241. [CrossRef]

Schmidt-Traub, Guido, Christian Kroll, Katerina Teksoz, David Durand-Delacre, and Jeffrey D. Sachs. 2017. National Baselines for the Sustainable Development Goals Assessed in the SDG Index and Dashboards. *Nature Geoscience* 10: 547–55. [CrossRef]

Schoenaker, Niels, Rutger Hoekstra, and Jan Pieter Smits. 2015. Comparison of Measurement Systems for Sustainable Development at the National Level. *Sustainable Development* 23: 285–300. [CrossRef]

Scrase, J. Ivan, and William R. Sheate. 2002. Integration and Integrated Approaches to Assessment: What Do They Mean for the Environment? *Journal of Environmental Policy & Planning* 4: 275–94. [CrossRef]

Shaker, Richard Ross. 2015. The Spatial Distribution of Development in Europe and Its Underlying Sustainability Correlations. *Applied Geography* 63: 304–14. [CrossRef]

Shi, Longyu, Linwei Han, Fengmei Yang, and Lijie Gao. 2019. The Evolution of Sustainable Development Theory: Types, Goals, and Research Prospects. *Sustainability* 11: 7158. [CrossRef]

Silva, Andréa Neiva da, Carla Ribeiro Guedes, Cláudia Du Bocage Santos-Pinto, Elaine Silva Miranda, Larissa Machado Ferreira, and Mario Vianna Vettore. 2021. Demographics, Socioeconomic Status, Social Distancing, Psychosocial Factors and Psychological Well-Being among Undergraduate Students during the COVID-19 Pandemic. *International Journal of Environmental Research and Public Health* 18: 7215. [CrossRef]

Stefanou, Joseph, and R. Miitoula. 2024. Global Goal 11 for Sustainable City Development. *Sustainable Development, Culture, Traditions Journal* 4: 58–68. [CrossRef]

Stern, Paul C. 1993. A Second Environmental Science: Human-Environment Interactions. *Science* 260: 1897–99. [CrossRef]

Strezov, Vladimir, Annette Evans, and Tim J. Evans. 2017. Assessment of the Economic, Social and Environmental Dimensions of the Indicators for Sustainable Development. *Sustainable Development* 25: 242–53. [CrossRef]

Suresh, P., and Liaquat Roopesh Johnson. 2015. The Post-2015 Agenda: From Millennium Development Goals (Mdgs) To Sustainable Development Goals (Sdgs). *International Journal of Current Research and Review* 7: 62–67.

Taneva, Tanya. 2023. Revisions to Maslow's Hierarchical Model of Basic Phychological Needs. *Trakia Journal of Sciences* 21: 222–30. [CrossRef]

Thapa, Prashamsa, Brijesh Mainali, and Shobhakar Dhakal. 2023. Focus on Climate Action: What Level of Synergy and Trade-Off Is There between SDG 13; Climate Action and Other SDGs in Nepal? *Energies* 16: 566. [CrossRef]

Tomaselli, Venera, Mario Fordellone, and Maurizio Vichi. 2021. Building Well-Being Composite Indicator for Micro-Territorial Areas Through PLS-SEM and K-Means Approach. *Social Indicators Research* 153: 407–29. [CrossRef]

Tompa, Orsolya, Anna Kiss, Matthieu Maillot, Eszter Sarkadi Nagy, Ágoston Temesi, and Zoltán Lakner. 2022. Sustainable Diet Optimization Targeting Dietary Water Footprint Reduction—A Country-Specific Study. *Sustainability* 14: 2309. [CrossRef]

Tremblay, David, François Fortier, Jean-François Boucher, Olivier Riffon, and Claude Villeneuve. 2020. Sustainable Development Goal Interactions: An Analysis Based on the Five Pillars of the 2030 Agenda. *Sustainable Development* 28: 1584–96. [CrossRef]

Tsangaris, Spyridon, Anastasios Xepapadeas, Athanasios N. Yannacopoulos, and Luca Salvati. 2024. Spatial Externalities, R&D Spillovers, and Endogenous Technological Change. *Regional Science and Urban Economics* 109: 104055. [CrossRef]

Tsangas, Michail, Iliana Papamichael, and Antonis A. Zorpas. 2023. Sustainable Energy Planning in a New Situation. *Energies* 16: 1626. [CrossRef]

Tsani, Stella, Phoebe Koundouri, and Ebun Akinsete. 2020. Resource Management and Sustainable Development: A Review of the European Water Policies in Accordance with the United Nations' Sustainable Development Goals. *Environmental Science & Policy* 114: 570–79. [CrossRef]

Udo, Victor E., and Peter Mark Jansson. 2009. Bridging the Gaps for Global Sustainable Development: A Quantitative Analysis. *Journal of Environmental Management* 90: 3700–3707. [CrossRef]

Unterhalter, Elaine, and Andrew Dorward. 2013. New MDGs, Development Concepts, Principles and Challenges in a Post-2015 World. *Social Indicators Research* 113: 609–25. [CrossRef]

van den Bosch, M., and Å Ode Sang. 2017. Urban Natural Environments as Nature-Based Solutions for Improved Public Health—A Systematic Review of Reviews. *Environmental Research* 158: 373–84. [CrossRef]

van Niekerk, Arno. 2020. Inclusive Economic Sustainability: SDGs and Global Inequality. *Sustainability* 12: 5427. [CrossRef]

Van Opstal, Maarten, and Jean Hugé. 2013. Knowledge for Sustainable Development: A Worldviews Perspective. *Environment, Development and Sustainability* 15: 687–709. [CrossRef]

van Zanten, Jan Anton, and Rob van Tulder. 2021. Towards Nexus-Based Governance: Defining Interactions between Economic Activities and Sustainable Development Goals (SDGs). *International Journal of Sustainable Development & World Ecology* 28: 210–26. [CrossRef]

Vandemoortele, Jan. 2011. The MDG Story: Intention Denied. *Development and Change* 42: 1–21. [CrossRef]
Vardopoulos, Ioannis. 2019. Critical Sustainable Development Factors in the Adaptive Reuse of Urban Industrial Buildings. A Fuzzy DEMATEL Approach. *Sustainable Cities and Society* 50: 101684. [CrossRef]
Vardopoulos, Ioannis, Agapios Demosthenous, and Roido Mitoula. 2024a. A Paradigm Shift in Real Estate Dynamics: Unravelling the Blueprint for Urban Well-Being. In *1st Open-Air Cities International Conference: Local and Regional Sustainable Development and Urban Reconstruction, 16–18 February, 2024, Kallithea, Greece. Book of Abstracts*. Athens: Open-Air Cities Institute. ISBN 9786188707009.
Vardopoulos, Ioannis, Alessia D'Agata, Francisco Escrivà Saneugenio, and Luca Salvati. 2024b. *Sprawl and the City: Realizing a Sustainable Mediterranean Urbanization*. Hauppauge: Nova Science Publishers. ISBN 9798895300060. [CrossRef]
Vardopoulos, Ioannis, and Spyridon Karytsas. 2019. An Exploratory Path Analysis of Climate Change Effects on Tourism. *Sustainable Development, Culture, Traditions Journal* Special Volume in Honor of Professor George I. Theodoropoulos: 132–52. [CrossRef]
Vardopoulos, Ioannis, Christos Georgiou, Irene Voukkali, Constantinos Vassiliades, and Luca Salvati. 2024c. Case-Based Exploration of the Nexus between Transformative Urban Megadevelopments and Sustainability. *Theoretical and Empirical Researches in Urban Management* 19: 5–30.
Vardopoulos, Ioannis, Christos Stamopoulos, Georgios Chatzithanasis, Christos Michalakelis, Panagiota Giannouli, and Eleni Pastrapa. 2020. Considering Urban Development Paths and Processes on Account of Adaptive Reuse Projects. *Buildings* 10: 73. [CrossRef]
Vardopoulos, Ioannis, Evangelia Tsilika, Efthymia Sarantakou, A. A. Zorpas, Luca Salvati, and Paris Tsartas. 2021. An Integrated SWOT-PESTLE-AHP Model Assessing Sustainability in Adaptive Reuse Projects. *Applied Sciences* 11: 7134. [CrossRef]
Vardopoulos, Ioannis, Ioannis Vannas, George Xydis, and Constantinos Vassiliades. 2023a. Homeowners' Perceptions of Renewable Energy and Market Value of Sustainable Buildings. *Energies* 16: 4178. [CrossRef]
Vardopoulos, Ioannis, Marco Maialetti, Donato Scarpitta, and Luca Salvati. 2024d. Spatially Explicit Analysis of Landscape Structures, Urban Growth, and Economic Dynamics in Metropolitan Regions. *Urban Science* 8: 150. [CrossRef]
Vardopoulos, Ioannis, Maria Papoui-Evangelou, Bogdana Nosova, and Luca Salvati. 2023b. Smart 'Tourist Cities' Revisited: Culture-Led Urban Sustainability and the Global Real Estate Market. *Sustainability* 15: 4313. [CrossRef]
Vardopoulos, Ioannis, Sotiris Falireas, Ioannis Konstantopoulos, Elli Kaliora, and Eleni Theodoropoulou. 2018. Sustainability Assessment of the Agri-Environmental Practices in Greece. Indicators' Comparative Study. *International Journal of Agricultural Resources, Governance and Ecology* 14: 368. [CrossRef]
Vasseur, Liette, Mary J. Thornbush, and Steve Plante. 2022. Engaging Communities in Adaptation to Climate Change by Understanding the Dimensions of Social Capital in Atlantic Canada. *Sustainability* 14: 5250. [CrossRef]
Vinci, Sabato, Ioannis Vardopoulos, and Luca Salvati. 2023. A Tale of a Shrinking City? Exploring the Complex Interplay of Socio-Demographic Dynamics in the Recent Development of Attica, Greece. *Cities* 132: 104089. [CrossRef]
Wells, Jonathan C., Ana Lydia Sawaya, Rasmus Wibaek, Martha Mwangome, Marios S. Poullas, Chittaranjan S. Yajnik, and Alessandro Demaio. 2020. The Double Burden of Malnutrition: Aetiological Pathways and Consequences for Health. *The Lancet* 395: 75–88. [CrossRef]
Wibeck, Victoria, Björn-Ola Linnér, Melisa Alves, Therese Asplund, Anna Bohman, Maxwell T. Boykoff, Pamela M. Feetham, Yi Huang, Januario Nascimento, Jessica Rich, and et al. 2019. Stories of Transformation: A Cross-Country Focus Group Study on Sustainable Development and Societal Change. *Sustainability* 11: 2427. [CrossRef]
Wiesli, Thea Xenia, Ulf Liebe, Thomas Hammer, and Roger Bär. 2021. Sustainable Quality of Life: A Conceptualization That Integrates the Views of Inhabitants of Swiss Rural Regions. *Sustainability* 13: 9187. [CrossRef]
Wilson, Jeffrey, Peter Tyedmers, and Ronald Pelot. 2007. Contrasting and Comparing Sustainable Development Indicator Metrics. *Ecological Indicators* 7: 299–314. [CrossRef]
Winkler, Inga T., and Margaret L. Satterthwaite. 2017. Leaving No One behind? Persistent Inequalities in the SDGs. *The International Journal of Human Rights* 21: 1073–97. [CrossRef]
Wojewódzka-Wiewiórska, Agnieszka, Anna Kłoczko-Gajewska, and Piotr Sulewski. 2019. Between the Social and Economic Dimensions of Sustainability in Rural Areas—In Search of Farmers' Quality of Life. *Sustainability* 12: 148. [CrossRef]
Wojtkowiak, Daniel, and Piotr Cyplik. 2020. Operational Excellence within Sustainable Development Concept-Systematic Literature Review. *Sustainability* 12: 7933. [CrossRef]
Wong, Cecilia. 2015. A Framework for 'City Prosperity Index': Linking Indicators, Analysis and Policy. *Habitat International* 45: 3–9. [CrossRef]
Xue, Yongjie, Jinling Yan, Dahai Li, and Haijing Zheng. 2023. Integrated Ocean Management (IOM) for Marine Sustainable Development Goal (SDG)14: A Case Study of China's Bohai Sea. *Sustainability* 15: 5979. [CrossRef]
Yamin, Paulius, Maria Fei, Saadi Lahlou, and Sara Levy. 2019. Using Social Norms to Change Behavior and Increase Sustainability in the Real World: A Systematic Review of the Literature. *Sustainability* 11: 5847. [CrossRef]
Yawson, David O., Frederick A. Armah, and Alex N. M. Pappoe. 2009. Enabling Sustainability: Hierarchical Need-Based Framework for Promoting Sustainable Data Infrastructure in Developing Countries. *Sustainability* 1: 946–59. [CrossRef]
Yildiz, Ezgi Pelin. 2021. Academist Perceptions on the Use of Web 2.0 Tools Through Maslow's Needs Hierarchy: A Case Study. *Education Quarterly Reviews* 4: 173–88. [CrossRef]
Yin, Wei. 2019. Integrating Sustainable Development Goals into the Belt and Road Initiative: Would It Be a New Model for Green and Sustainable Investment? *Sustainability* 11: 6991. [CrossRef]

Zambon, Ilaria, Pere Serra, Efstathios Grigoriadis, Margherita Carlucci, and Luca Salvati. 2017. Emerging Urban Centrality: An Entropy-Based Indicator of Polycentric Development and Economic Growth. *Land Use Policy* 68: 365–71. [CrossRef]

Zhai, Tianlin, Mingyuan Chang, Yingchao Li, Longyang Huang, Ye Chen, Guanyu Ding, Chenchen Zhao, Ling Li, Weiqiang Chen, Panfeng Zhang, and et al. 2023. Integrating Maslow's Hierarchy of Needs and Ecosystem Services into Spatial Optimization of Urban Functions. *Land* 12: 1661. [CrossRef]

Zhang, Mingxia, Yang Chen, Oleksii Lyulyov, and Tetyana Pimonenko. 2022. Interactions between Economic Growth and Environmental Degradation toward Sustainable Development. *Systems* 11: 13. [CrossRef]

Zhou, Li, Hella Tokos, Damjan Krajnc, and Yongrong Yang. 2012. Sustainability Performance Evaluation in Industry by Composite Sustainability Index. *Clean Technologies and Environmental Policy* 14: 789–803. [CrossRef]

Zorpas, Antonis A. 2020a. Biosolids Composting and Soil Applications. In *Wastewater and Biosolids Management*. Edited by Ioannis K. Kalavrouziotis. London: IWA Publishing, pp. 107–20. [CrossRef]

Zorpas, Antonis A. 2020b. Strategy Development in the Framework of Waste Management. *Science of The Total Environment* 716: 137088. [CrossRef] [PubMed]

Zorpas, Antonis A., ed. 2014. *Sustainability behind Sustainability*. Hauppauge: Nova Science Publishers. ISBN 9781633215733.

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Article

Demographic Change and Regional Specialisation: The Case of Greek NUTS II Regions

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Abstract: This paper investigates the impact of demographic changes on regional specialisation across Greek NUTS2 regions from 2001 to 2021. It explores the relationship between age-specific variations in the economically active population and gross value added (GVA) across different economic sectors. Using demographic and GVA data alongside spatial analysis techniques such as spatial regression models, median Local Moran's I, and location quotient, the study identifies spatial autocorrelation patterns. Findings reveal strong correlations between the economically active population and GVA, highlighting demographic factors' crucial role in regional economic performance. Over the period 2001 to 2021, the 15–24 and 25–34 age groups generally experienced declining growth rates in total, male, and female economically active populations, while the 45–54 and 55–64 age groups saw increases. Regions adjacent to those with higher economically active populations showed high–high clustering. Especially, Attiki and Kentriki Makedonia, the two metropolitan regions of Greece, influence neighbouring regions through economic spillover effects, fostering economic sector clustering and emphasising regional specialisation. These findings highlight the complex interplay between demographic shifts and regional economic outcomes, noting spatial disparities and the need for targeted policy interventions. The study provides empirical evidence demonstrating how demographic changes influence regional economic development across different regions.

Keywords: Greek NUTS2 regions; economically active population; gross value added; local Moran's I; location quotient

1. Introduction

Demographic change affects regional specialisation by altering labour and consumer markets. Alternatively, regional specialisation influences demographic patterns, attracting specific populations that further enhance local strengths and economic growth. Several researchers have addressed different aspects of demographic change in recent years. Gómez and de Cos Pablo (2008) demonstrated that population ageing positively correlated with economic performance across countries. They found that an optimal ratio of prime-age workers relative to younger workers maximised GDP per capita, highlighting demographic effects on economic productivity. Kurek (2011) examined ageing patterns in post-socialist Poland up to 2030, revealing spatially varied distributions of elderly populations. The study linked demographic ageing with societal transitions, highlighting vulnerable regions amidst political and economic changes. Siliverstovs et al. (2011) found that ageing significantly affected employment shares across various sectors, with an increase in the elderly population negatively impacting agriculture, manufacturing, construction, and mining while benefitting community services and the financial sector. Franklin (2012) analysed US population changes from 2000 to 2010, finding that while the overall population grew, the composition varied by age and race/ethnicity. Shift-share analysis identified regions where growth stemmed from demographic advantages in specific age cohorts or racial/ethnic groups. Göbel and Zwick (2012) examined the impact of an ageing workforce on productivity across different sectors using linked employer-employee panel data, finding no significant differences in age-productivity profiles between manufacturing and services, despite varying sector characteristics. Mahlberg et al. (2013) examined the relationship between age structure and labour productivity in Austria using matched employer–employee data. They found significant variations in the age-productivity pattern across different regions and sectors, with sectoral differences being the primary source of heterogeneity. Shiode et al. (2014) utilised both ageing population ratio and density to analyse ageing communities in Aichi Prefecture, Japan, indicating that this dual approach effectively identified diverse ageing community types across urban and rural settings. Lin et al. (2015) found that in Taiwan from 1998 to 2006, regional household income inequality was influenced by ageing demographics, specifically due to shifts from multigenerational to elderly households without additional income. They identified spatial clustering and observed both convergence and divergence dynamics, emphasising the need for spatially aware policy considerations. Cai and Stoyanov (2016) found that demographic differences significantly influenced international trade dynamics, as population ageing reduced the supply of age-dependent skills, leading younger labour force countries to excel in industries relying on younger workers while older populations specialised in age-appreciating skills, diminishing their comparative advantage. Cuadrado-Roura et al. (2016) emphasised that Mediterranean regions with high unemployment and economic decline during the crisis exhibited different economic dynamics. Regions undergoing demographic transitions, like ageing populations, experienced significant impacts on their economic specialisation and output. Cuaresma et al. (2016) found that demographic trends, particularly ageing, would slow income convergence across Europe, concluding that policies aimed solely at improving labour force participation were insufficient to counteract the negative effects of ageing. Peterson (2017) examined 200 years of data to explore the complex relationship between population growth, per capita output, and overall economic growth. Low population growth in wealthy nations and high growth in poorer nations exacerbated global economic inequality, despite potential benefits of international migration. Danko and Hanink (2018) used demographic shift-share analysis to compare racial and ethnic population changes in shrinking (Buffalo, Cleveland, Detroit, Pittsburgh, St. Louis) and growing (Atlanta, Denver, Phoenix, San Diego, Seattle) US cities from 1990 to 2010. They found growth among Mexican, Puerto Rican, Asian, and foreign-born populations despite declines in White and Black populations in shrinking cities. Seok et al. (2018) found that ageing negatively impacted farm efficiency in Korea, showing continuous declines rather than the expected inverted-U relationship. Additionally, income subsidies had a detrimental effect on efficiency, suggesting the need for policy adjustments to encourage youth participation in agriculture. Wessel et al. (2018) found that in Oslo between 2001 and 2011, local mobility among ethnic groups increased own-group exposure and separation from the Nordic majority, while international migration promoted integration between Nordic and non-Nordic residents. Cheng et al. (2019) found that from 2000 to 2010, rural areas in China experienced more rapid population ageing compared to urban areas. Spatial analysis identified expanding clusters of ageing populations from coastal to inland regions, highlighting disparities in health, economic status, and ageing challenges at the prefectural level. Dolls et al. (2019) found that demographic changes likely increased income inequality in the EU-27 by 2030, but wage adjustments counteracted this trend. EU tax-benefit systems largely absorbed the projected rise in market income inequality. Liu et al. (2019) investigated the impact of an ageing agricultural labour force on technical efficiency in southwestern China. They found a negative relationship between ageing and technical efficiency, highlighting the need for policy measures to address these challenges. Feng et al. (2020) found that China's ageing population has accelerated faster than in developed and BRICS countries, with significant regional and urban–rural disparities. Factors like urbanisation and regional GDP deepened the ageing gap, but population density had no significant impact. Kim et al. (2020) found that Daegu's ageing regions expanded rapidly from the city centre between 2009 and 2018. Neighbourhood conditions in these areas were poor, especially regardingaccessibility and safety, with significant differences between urban and suburban environments. OECD (2020) revealed that the Greek economy exhibited persistent regional imbalances, with Attiki, particularly the capital of Athens, dominating in GDP per capita and population. This concentration led to significant growth but also caused environmental and social issues. Okada (2020) demonstrated that demographic changes and human capital accumulation influenced R&D activity differently across steady states: high human capital correlated with high R&D activity, low fertility, and high old-age survival. Improved public health policies had an inverted U-shaped effect on economic growth rates at steady states, indicating potential for government intervention to mitigate poverty traps. Papapetrou and Tsalaporta (2020) found that population ageing negatively impacted real GDP growth and reduced inflation in 23 OECD countries. They recommended labour market policies, pension reforms, and investments in human capital to mitigate these adverse effects. Han and Chung (2021) found that ageing and underemployment negatively affected household income in South Korea, with a more pronounced impact in the agricultural sector compared to non-agricultural households. Policy simulations indicated that targeted government interventions could help reduce income disparity between these sectors. Hirono (2021) demonstrated that the impact of increased life expectancy on income growth per capita depended on the productivity of the non-education and education sectors, revealing a potential non-linear relationship between ageing and economic growth. Iwasaki (2021) analysed population changes between central city densely inhabited districts (DIDs) and surrounding DIDs in Japan from 1960 to 2015. The study revealed that population decline in central city DIDs was influenced by factors such as youth outmigration, business relocation, and social decline due to residential shifts to areas outside central city DIDs. Kashnitsky et al. (2021) found that from 2003 to 2013, contrary to expectations, age structures did not diverge between urban and rural NUTS2 regions of the EU-27. Instead, divergence occurred within each group of regions, indicating complex demographic dynamics. Lee and Shin (2021) investigated how population ageing impacts per capita output growth in 35 OECD countries through six channels. They confirmed that ageing negatively affects GDP growth, primarily through reduced total factor productivity (TFP), which they found to have lasting effects on economic growth. Chen et al. (2022) examined population ageing in rural China from 2000 to 2020, finding increased ageing with spatial heterogeneity. The study identified key factors, such as population structure and fertility rates, influencing ageing patterns and emphasised the need for collaboration to address these challenges. DiPasquale (2022) underscored the importance of understanding the interplay between demographic factors and economic outcomes, emphasising that demographic shifts had profound effects on economic performance. Xu et al. (2022) discovered that China's ageing industry developed unevenly, with regional disparities narrowing over time. Economic disparities increased, particularly between eastern and northeastern regions. Coordinated development between the ageing industry and regional economy positively impacted neighbouring regions. Bode et al. (2023) revealed that ageing negatively impacted regional productivity growth in Germany, with workforce ageing affecting urban areas more due to its detrimental effects on innovation. Additionally, a higher share of retirees reduced productivity in regions with small household services sectors. Borda et al. (2023) identified that the ageing agricultural population posed a global challenge, with younger generations reluctant to take over farms due to low income, poor working conditions, limited land access, and administrative burdens. Chung and Hean (2023) found that in the United States, regional population ageing positively impacted employment growth and rent levels, with no significant effect on local wages. These results suggest that an ageingpopulation may enhance local production and consumption amenities, contradicting expectations of negative economic impacts. Jayawardhana et al. (2023) explored the causal relationship between the Per Capita Gross Domestic Product growth rate and the elderly population in 15 European countries, finding varied causality patterns and a historical shift in the impact between the two variables. Malmberg et al. (2023) demonstrated that demographic transitions and changes in population age structure have significantly influenced global economic development since 1950, with regional and urban shifts in Western Europe and North America highlighting the overlooked impact of ageing on economic geography. Mariscal-de-Gante et al. (2023) found that increased female participation resulted in job polarisation, particularly through low-paid jobs. Educational returns declined more for women, while occupational profiles for young and old workers changed similarly, with persistent gender-based differences. Shen et al. (2023) reported a positive relationship between rural population ageing and agricultural labour productivity in China. Ageing stimulated agricultural development by promoting structural adjustments and modernisation, though this positive effect weakened as ageing deepened further. Zhang et al. (2023) found that the ageing rural labour force in China weakened agricultural economic resilience. As rural labour ageing increased, agricultural resilience declined, mainly due to reduced human capital and limitations in scale management and technological progress, especially in less-developed regions. Santos (2024) examined GDP trends and ageing dynamics in Portugal from 2011 to 2021, revealing that regions with a higher GDP tended to have younger populations, while lower GDP regions had older populations. The study underscored the need for tailored policies addressing demographic and economic disparities across regions. Song et al. (2024) found that the ageing rural population negatively affected agricultural green total factor productivity in China. This impact was particularly significant in western regions, with ageing inhibiting labour productivity, innovation, and farmland transfer, especially under stricter environmental regulations. Zhang et al. (2024) discovered that population ageing significantly influenced China's service industry, exhibiting an "inverted U" effect. The study revealed regional and industry heterogeneity, with notable impacts in developed regions and medical industries, and identified a threshold beyond which ageing's positive effects diminish.

This paper introduces several novel contributions in the context of the existing literature on demographic changes and regional economic specialisation. Unlike previous studies that have often focused on a single aspect of demographic change, such as ageing or migration, this paper comprehensively examines the economically active population across various age groups and genders, providing a nuanced understanding of demographic shifts in Greece over two decades. By employing advanced spatial analysis techniques, including Spatial Regression Models, Local Moran's I, and Location Quotient, the paper uniquely identifies the spatial clustering and regional specialisation effects of demographic changes on economic performance. Additionally, the inclusion of gross value added (GVA) across 11 distinct economic branches offers a more detailed exploration of how demographic dynamics influence specific sectors differently, revealing intricate relationships between demographic patterns and economic outcomes at the regional level. This multi-faceted approach, particularly within the Greek context, where regional disparities are pronounced, sets this paper apart from prior research, offering actionable insights for policymakers.

2. Methodology

The present paper employs demographic data of the total, male, and female economically active populations for Greek NUTS2 regions, examining different age groups, including 15 to 24 years, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, and 65 years or over (Eurostat 2024a). Moreover, it utilises gross value added from 11 economic branches, according to Eurostat classification, which are:"Agriculture, forestry and fishing", "Energy", "Manufacturing", "Construction", "Wholesale and retail trade, transport, accommodation and food service activities", "Information and communication", "Financial and insurance activities", "Real estate activities", "Professional, scientific and technical activities, administrative and support service activities", "Public administration, defence, education, human health and social work activities", "Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organisations and bodies" for 2021 and 2001 at Greek NUTS2 regional level (Eurostat 2024b). To sum up, the analysis concerns the 13 Greek NUTS2 regions, as illustrated in the Figure 1.

Figure 1. Greek NUTS2 regions.

Regarding the methodology, spatial regression models, Local Moran's I method and Location Quotient are used. Based on regression analysis, the Spatial Lag and Spatial Error models (Anselin 1988) are implemented in the analysis.

The Spatial Lag Model is specified as follows:

$$GVA = \rho WGVA + \beta EAP + \varepsilon \tag{1}$$

- GVA: Gross Value Added in the 13 Greek NUTS2 regions.
- EAP: Economically Active Population in the 13 Greek NUTS2 regions.
- ρ: Spatial autoregressive coefficient, capturing the influence of neighbouring regions' GVA on a given region's GVA.
- WGVA: Spatially lagged GVA, where W is a spatial weights matrix defining the relationships between regions.
- β: Coefficient for the EAP variable.
- ε: Error term.

The Spatial Error Model is specified as follows:

$$GVA = \beta EAP + u \tag{2}$$

$$u = \lambda Wu + \varepsilon \tag{3}$$

- GVA: Gross Value Added in the 13 Greek NUTS2 regions.
- EAP: Economically Active Population in the 13 Greek NUTS2 regions.
- β: Coefficient for the EAP variable.
- u: Spatially autocorrelated error term.
- λ: Spatial autocorrelation coefficient, capturing the spatial dependence in the errors.
- Wu: Spatially lagged error term.
- ε: Normally distributed error term.

In the Local Moran's I method, each observation is assigned a statistic that can be mapped to reveal spatial patterns. Below is the equation of traditional Local Moran's I (Anselin 1995):

$$I_i = \frac{(x_i - \overline{x})}{S^2} \sum_{j=1}^{n} w_{ij}(x_j - \overline{x}) \quad (4)$$

where in the analysis:

- I_i: the Local Moran's I statistic for region i with respect to either economically active population or gross value added.
- x_i and x_j: the values of the economically active population or gross value added in regions i and j, respectively.
- $\overline{x}$: the mean of the economically active population or gross value added across all regions.
- S^2: the sample variance of the economically active population or gross value added.
- w_{ij}: the spatial weight between regions i and j.
- n: is the total number of regions.

However, the median Local Moran's I is utilised by the paper. The specific method is applied by the economically active population and gross value added data too. This method uses the median of the Local Moran's I values, which makes it less sensitive to extreme values than the traditional Local Moran's I.

So, the Median Local Moran's I calculates the median of all Local Moran's I statistics across regions:

$$MLI = \text{median}(I_1, I_2, \ldots I_n) \quad (5)$$

where MLI is the Median Local Moran's I statistic and I_i is the Local Moran's I statistic for region i.

While, in a relevant cluster map:

- High–High: Indicates regions with high values surrounded by neighbouring regions with high values as well
- Low–High: Indicates regions with low values surrounded by neighbouring regions with high values.
- High–Low: Indicates regions with high values surrounded by neighbouring regions with low values.
- Low–Low: Indicates regions with low values surrounded by neighbouring regions with low values as well.

Furthermore, the location quotient implements to identify the specialisation of each Greek region in each examined economic branch. The location quotient (LQ) is given by the specific equation (Isserman 1977):

$$LQ = \frac{GVA_{ir}}{GVA_{in}} \Big/ \frac{GVA_r}{GVA_n} \quad (6)$$

In the analysis, GVA is the examined gross value added, i: the economic branches, r: the NUTS2 region and n: the country. If the location quotient is greater than one, it means that the NUTS2 region r is specialised in the examined economic branch i.

The use of only 13 NUTS2 regions in this study presents certain challenges, particularly concerning the spatial model's robustness, given the relatively small number of spatial units. However, this choice is justified by the fact that these regions represent critical administrative and economic divisions within Greece, making them highly relevant for regional policy analysis. While the use of more granular NUTS3 data would have been preferable, such data is either not available or lacks the consistency needed for robust modelling at that level. To compensate for this limitation, the analysis incorporates a panel dataset covering the years 2001 and 2021, effectively increasing the temporal depth and sample size. This approach strengthens the model's validity by capturing long-term spatial dynamics and reducing the risks associated with cross-sectional limitations. The implementation of spatial regression techniques, such as the Spatial Lag and Spatial Error models, further addresses these challenges by accounting for spatial dependencies between regions, ensuring that spillover effects between neighbouring regions are captured and that bias is reduced in the results. Moreover, the Local Moran's I statistic, particularly its median-based version, allows for the identification of spatial clusters and localised patterns of economic performance, mitigating the impact of extreme outliers and providing a more nuanced understanding of spatial relationships. Additionally, the study utilises the Location Quotient (LQ) to examine regional specialisation across 11 economic sectors, offering a complementary non-spatial perspective. The LQ identifies regions with specific sectoral strengths by comparing each region's sectoral Gross Value Added (GVA) against the national average. A value above one indicates that a region is specialised in that sector, offering insight into its comparative advantage. This dual use of spatial and non-spatial methods, including both spatial regression and LQ analysis, provides a well-rounded approach, enhancing the study's overall analytical robustness despite the limited spatial units. By integrating these methodologies, the study delivers a comprehensive examination of regional economic development patterns in Greece.

3. Results

Beginning with the analysis of the paper, the Figure 2 illustrates the Pearson correlation between economically active population and gross value added for the years 2021 and 2001.

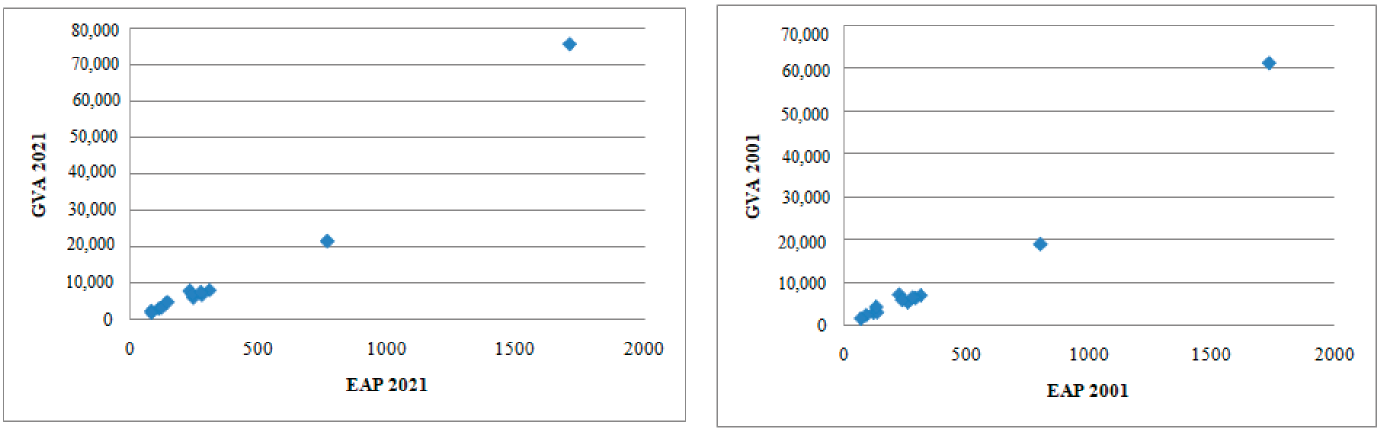

Figure 2. Pearson correlation.

So, Figure 2 presents the r values of 0.987 (2021) and 0.988 (2001) respectively, indicating that variations in economically active population closely predict variations in gross value added. The near-perfect r values suggest that economically active population is a crucial determinant of gross value added. This strong correlation highlights the critical role of a robust workforce in driving regional economic performance. Table 1 indicates the results of spatial regression models between economically active population and gross value added for 2021 and 2001.

According the above table, the Spatial Lag Model (SLM) indicates a strong spatial lag effect with a coefficient of 0.692, meaning gross value added in a region is significantly influenced by gross value added in neighbouring regions in both years. The economically active population coefficient is highly significant in both years, with values of 46.429 for 2021 and 36.858 for 2001, showing that an increase in the economically active population positively impacts gross value added. The Akaike Information Criterion (AIC) values for the SLM are 249.748 for 2021 and 243.565 for 2001, suggesting a slightly better fit for the 2001 model. The Spatial Error Model (SEM) reveals a significant Lambda coefficient of 1.444 in both years, indicating substantial spatial autocorrelation in the error terms. This suggests that unobserved spatial effects are significant. The economically active population remains a significant predictor of gross value added, with coefficients of 46.429 for 2021 and 34.847 for 2001. The AIC values for the SEM are 247.748 for 2021 and 241.565 for 2001, indicating a marginally better fit compared to the SLM. Overall, while both models capture significant spatial dependencies, the SEM provides a slightly better fit, highlighting the importance of accounting for spatial autocorrelation in the error terms.

Table 1. SLM and SEM results.

Spatial Lag Model					Spatial Error Model				
Variable 2021	**Coefficient**	**Std.Error**	**z-Value**	**Probability**	**Variable 2021**	**Coefficient**	**Std.Error**	**z-Value**	**Probability**
W_GVA	0.692	0.221	313.126	0.002	EAP	46.429	2.236	20.762	0.000
EAP	46.429	2.236	20.762	0.000	LAMBDA	1.444	0.338	4.270	0.000
Lag coeff. (Rho)	0.692				Lag coeff. (Lambda)	1.444			
Akaike info criterion	249.748				Akaike info criterion	247.748			
Variable 2001	**Coefficient**	**Std.Error**	**z-Value**	**Probability**	**Variable 2001**	**Coefficient**	**Std.Error**	**z-Value**	**Probability**
W_GVA	0.692	0.221	313.126	0.002	EAP	34.847	1.529	22.792	0.000
EAP	36.858	1.740	21.183	0.000	LAMBDA	1.444	0.338	4.270	0.000
Lag coeff. (Rho)	0.692				Lag coeff. (Lambda)	1.444			
Akaike info criterion	243.565				Akaike info criterion	241.565			

The next tables present demographic data of the total, male, and female economically active populations for Greek NUTS2 regions, focusing on different age groups: 15 to 24 years, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, and 65 years or over. For each age group, the 2021 population count and the percentage growth rate between 2021 and 2001 are provided. The specific tables assist in identifying the regions with the highest and lowest economically active populations and their growth trends. Moreover, the next figures present maps of univariate median local Moran's I for the total, male, and female economically active populations. These maps are used to visualise and analyse the spatial autocorrelation of the economically active populations across different regions. By examining the local Moran's I values, the study can identify clusters of regions with similar or dissimilar levels of economically active populations, which can reveal underlying spatial patterns and trends.

Beginning the analysis, based on Eurostat's (2024c) data, the total population of Greece in 2021 was 10,678,632. The male population was 5,196,048, while the female population was 5,482,584. Between 2001 and 2021, the total population declined by 1.45%. During the same period, the male population decreased by 2.51%, and the female population decreased by 0.42%.According to Table 2, Attiki (Greece's largest metropolitan region which includes the capital city of Athens) exhibits the highest total economically active population in 2021. It is followed by Kentriki Makedonia (the second largest metropolitan region of Greece, located in the north and bordering Bulgaria and the Republic of North Macedonia). On the other hand, Voreio Aigaio (an insular region located in the northeast part of the Aegean Sea, sharing marine borders with Turkey) has the lowest total economically active population. However, this particular region shows a notable growth rate compared to other Greek regions.

Table 2. Total economically active population for 2021 and its percentage growth rate 2001–2021.

NUTS2	15 to 24 Years		25 to 34 Years		35 to 44 Years		45 to 54 Years		55 to 64 Years		65 Years or Over		Total	
	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %
Anatoliki Makedonia, Thraki	16.30	−50.61	53.20	−19.39	63.10	−4.97	68.00	24.31	41.60	16.53	3.80	−41.54	246.00	−6.21
Kentriki Makedonia	27.70	−70.50	152.40	−35.18	205.20	−4.20	234.90	42.11	130.00	58.73	16.50	47.32	766.70	−4.35
Dytiki Makedonia	5.60	−58.21	22.40	−35.63	28.80	−15.54	33.60	31.25	18.30	36.57	3.00	50.00	111.70	−9.41
Ipeiros	3.80	−71.21	22.10	−39.95	32.30	−7.71	37.50	20.97	23.00	25.00	3.70	−7.50	122.40	−11.56
Thessalia	16.70	−50.59	56.80	−34.11	78.70	−1.99	88.70	35.01	55.50	45.67	12.70	12.39	309.10	−2.00
Sterea Ellada	12.80	−57.89	48.20	−25.85	59.00	4.24	65.30	47.40	41.80	60.15	5.00	−9.09	232.10	1.84
Ionia Nisia	4.00	−51.22	14.80	−36.75	21.40	−10.46	23.60	19.80	16.60	34.96	2.90	−51.67	83.30	−10.91
Dytiki Ellada	20.40	−44.11	57.60	−30.52	70.30	−6.76	74.80	23.23	49.60	50.30	6.70	21.82	279.40	−4.97
Peloponnisos	8.00	−58.76	45.40	−23.44	62.00	−5.34	71.50	34.40	47.20	43.90	8.70	−7.45	242.80	1.34
Attiki	77.20	−60.57	351.80	−35.83	485.60	1.02	494.30	38.19	263.80	97.16	36.20	138.16	1708.90	−1.30
Voreio Aigaio	5.50	−38.89	19.50	−5.80	20.10	11.05	22.30	50.68	13.40	63.41	2.60	44.44	83.40	14.88
Notio Aigaio	6.40	−65.59	31.00	−24.21	40.00	16.62	40.30	52.65	22.10	82.64	5.00	163.16	144.80	7.90
Kriti	12.30	−62.50	57.20	−29.99	77.90	13.56	77.70	47.44	43.00	28.74	7.40	−44.78	275.50	−2.51

Attiki shows the highest national economically active population for the 15 to 24 years age group in the most recent examined year. On the other hand, Ipeiros (located in the northwestern corner of the Greek peninsula, the most mountainous region which borders Albania) has the lowest economically active population and the highest decline in terms of growth rate. In the 25 to 34 years age group, Attiki again leads with the highest economically active population. Ionia Nisia (an insular region that is located in the western part of Greece with marine borders with Albania and Italy), however, shows the lowest economically active population. In terms of growth rate, Ipeiros, as in the previous age group, indicates the highest decline. For the 35 to 44 years age group, Attiki holds the highest economically active population, while the region of Voreio Aigaio has the lowest. On the other hand, the region of Notio Aigaio (an insular region that is located in the centre of the Aegean Sea with marine borders with Turkey) shows the highest growth rate among the other Greek regions. In the 45 to 54 years age group, Attiki has the highest economically active population. The lowest is observed in Voreio Aigaio. However, regions such as Notio Aigaio indicate the highest growth rate in that age group. In the 55 to 64 age group, Attiki has the highest economically active population in 2021, as well as the highest growth rate between 2001 and 2021, while Voreio Aigaio has the lowest economically active population overall. Finally, for those aged 65 years or over, Attiki has the highest economically active population in 2021, while Voreio Aigaio has the lowest; the region of Notio Aigaio shows the highest growth rate.

Figure 3 portrays clusters of total economically active population in the 13 Greek NUTS2 regions for the years 2021 (left) and 2001 (right). In both maps, the region of Peloponnisos (located in the southern part of the mainland) is classified as High–High, indicating a high economically active population surrounded by similar regions. Many regions of continental Greece, including Dytiki Makedonia (located in the northwest of Greece, bordering Albania and the Republic of North Macedonia), Ipeiros, Sterea Ellada (located in the central part of mainland Greece) and regions such as Ionia Nisia, Voreio and Notio Aigaio, fall into the Low–High group, indicating low economically active populations surrounded by high values. Finally, the High–Low group, indicating high economically active populations surrounded by low values, includes regions such as Anatoliki Makedonia–Thraki (located in the northeast part of Greece, bordering Bulgaria and Turkey), Kentriki Makedonia, Thessalia (located at the centre of the eastern part of the Greek peninsula, between the two metropolitan regions of Attiki and Kentriki Makedonia), Dytiki Ellada (located in the western part of mainland Greece), Attiki, and Kriti (an insular region in southern Greece).

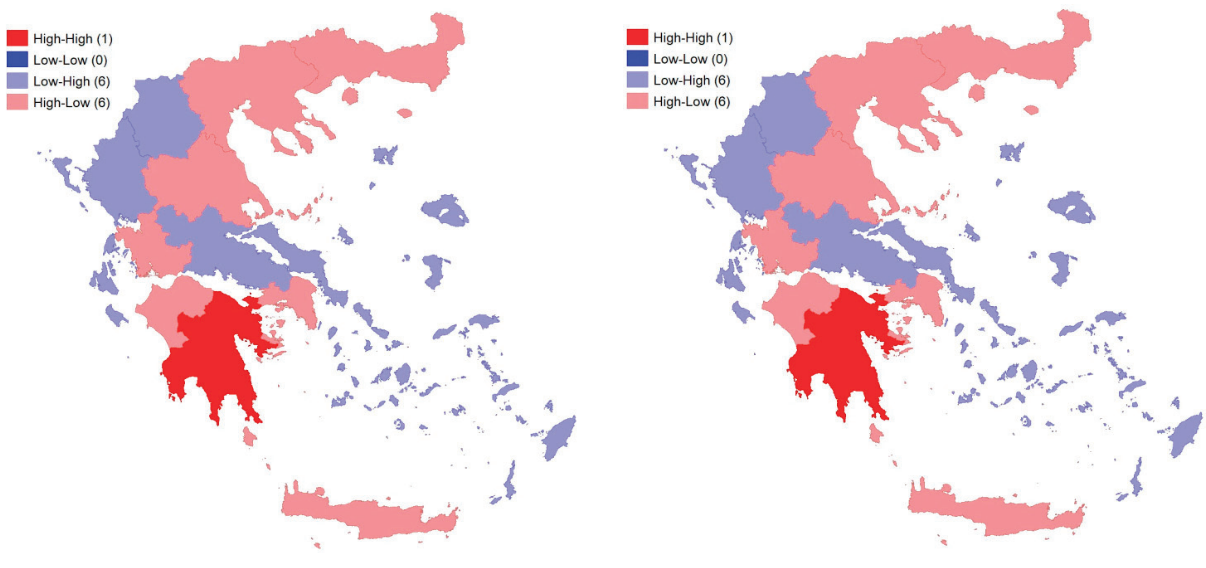

Figure 3. Cluster maps of total economically active population for 2021 and 2001.

Based on Table 3, Attiki boasts the highest male economically active population, followed by Kentriki Makedonia, while Ionia Nisia registers the lowest. All regions, including these, show considerable declines in their percentage growth rates between 2001 and 2021. For the age group 15 to 24 years, Attiki also leads in the male economically active population, with Ionia Nisia recording the lowest. Kentriki Makedonia undergoes the highest decline in this age group. In the 25 to 34 years age group, Attiki retains the highest male economically active population, with Ionia Nisia the lowest. Dytiki Makedonia reports the highest decline in this category. For ages 35 to 44 years, Attiki records the highest population, while Voreio Aigaio indicates the lowest. Kriti leads in percentage growth for this age group. For the 45 to 54 years age group, Attiki shows the highest male economically active population, and Voreio Aigaio the lowest, with Kriti demonstrating the highest growth rate. In the 55 to 64 years age group, Attiki not only registers the highest male population but also the highest growth rate, whereas Voreio Aigaio notes the lowest population. Finally, for those aged 65 years or over, Attiki exhibits the highest male economically active population, Ionia Nisia the lowest and Notio Aigaio achieves the highest growth rate between 2001 and 2021.

Figure 4 depicts clusters of the male economically active population in Greece's 13 NUTS2 regions for 2021 and 2001. For the most recent year, Sterea Ellada is classified as High–High, with high values surrounded by similar regions. Dytiki Makedonia, Ipeiros, Ionia Nisia, Voreio Aigaio, Notio Aigaio, and Peloponnisos fall into the Low–High category, with low values surrounded by high ones. Anatoliki Makedonia–Thraki, Kentriki Makedonia, Thessalia, Dytiki Ellada, Attiki, and Kriti are in the High–Low category, featuring high values surrounded by lower ones.

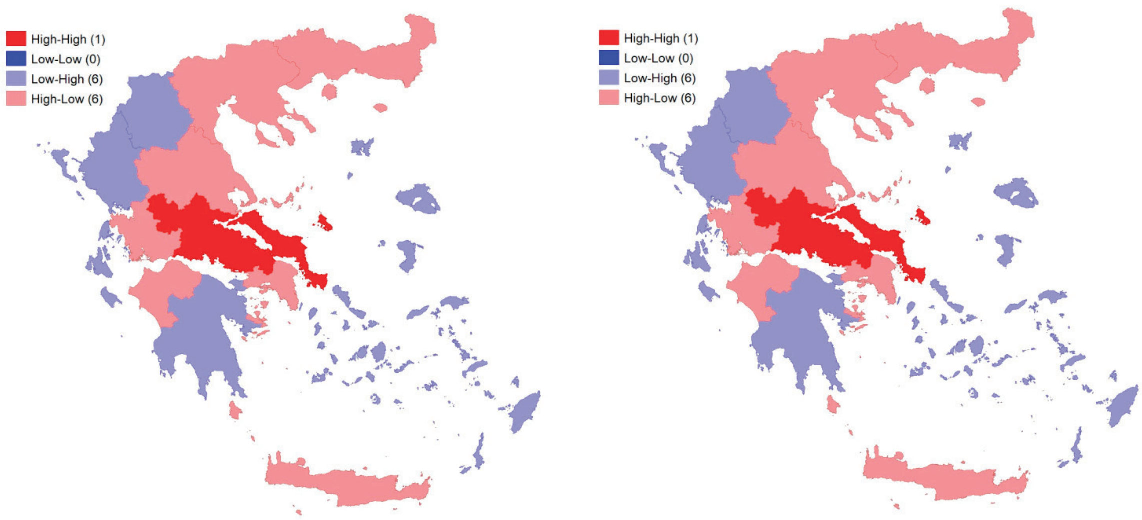

Figure 4. Cluster maps of male economically active population for 2021 and 2001.

In Table 4, Attiki has the highest female economically active population in 2021, followed by Kentriki Makedonia, while Voreio Aigaio has the lowest. These regions, along with others, show significant percentage growth in the female economically active population between 2001 and 2021. For the age group 15 to 24 years, Attiki again leads, with Ipeiros having the lowest female population. Notio Aigaio experiences the highest decline in this age group. In the 25 to 34 years age group, Attiki has the highest female population, while Ionia Nisia has the lowest. Voreio Aigaio shows the highest growth rate for this group. For ages 35 to 44 years, Attiki holds the highest female population, and Ionia Nisia the lowest. Voreio Aigaio leads in growth rate. In the 45 to 54 years age group, Attiki maintains the highest female population, with Ionia Nisia the lowest, and Voreio Aigaio showing the highest growth rate. In the 55 to 64 years age group, Attiki boasts the highest female population and the highest growth rate, while Voreio Aigaio displays the lowest population. Finally, for those aged 65 years or over, Attiki retains the highest female population, Dytiki Makedonia records the lowest, and Notio Aigaio achieves the highest growth rate between 2001 and 2021.

Table 3. Male economically active population for 2021 and its percentage growth rate 2001–2021.

NUTS2	15 to 24 Years		25 to 34 Years		35 to 44 Years		45 to 54 Years		55 to 64 Years		65 Years or Over		Total	
	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %
Anatoliki Makedonia, Thraki	9.60	−48.66	31.20	−18.54	35.80	−7.97	37.10	8.48	25.10	14.09	2.00	−55.56	140.80	−10.09
Kentriki Makedonia	15.30	−70.00	80.10	−40.80	118.20	−7.44	128.70	23.16	75.60	25.17	10.60	19.10	428.50	−12.18
Dytiki Makedonia	2.90	−60.27	11.80	−42.44	15.70	−26.29	20.10	20.36	10.60	37.66	1.90	90.00	63.00	−15.44
Ipeiros	2.50	−67.11	12.90	−39.15	18.90	−14.48	20.80	−1.42	14.50	22.88	2.00	−25.93	71.60	−17.11
Thessalia	8.00	−55.06	30.70	−38.72	44.60	−8.04	48.40	12.56	29.30	14.45	8.10	5.19	169.10	−12.30
Sterea Ellada	7.30	−55.49	27.70	−30.92	36.20	−4.74	40.00	29.45	25.40	43.50	3.40	−8.11	140.00	−4.63
Ionia Nisia	1.70	−62.22	8.10	−40.88	12.20	−16.44	13.60	9.68	9.40	23.68	1.50	−53.13	46.50	−16.96
Dytiki Ellada	10.30	−53.39	33.10	−35.73	41.70	−14.90	44.50	7.49	30.20	35.43	4.70	2.17	164.50	−13.83
Peloponnisos	3.90	−63.55	24.90	−26.55	35.50	−9.44	39.20	21.36	27.50	30.95	5.00	−21.88	136.00	−5.23
Attiki	40.90	−59.10	183.30	−40.02	259.90	−5.94	256.70	11.22	150.40	53.16	27.30	127.50	918.50	−10.20
Voreio Aigaio	3.70	−28.85	11.60	−10.08	10.80	−15.63	12.10	11.01	7.30	32.73	1.50	66.67	47.00	−2.49
Notio Aigaio	4.40	−59.26	18.20	−26.32	22.00	0.46	21.90	19.02	12.70	45.98	3.40	161.54	82.60	−3.85
Kriti	8.10	−57.14	32.00	−32.35	42.30	6.28	42.70	36.42	23.50	13.53	4.20	−48.15	152.80	−7.95

Table 4. Female economically active population for 2021 and its percentage growth rate 2001–2021.

NUTS2	15 to 24 Years		25 to 34 Years		35 to 44 Years		45 to 54 Years		55 to 64 Years		65 Years or Over		Total	
	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %	2021	Growth %
Anatoliki Makedonia. Thraki	6.70	−53.15	22.00	−20.58	27.20	−1.09	30.90	50.73	16.50	20.44	1.80	−14.29	105.10	−0.66
Kentriki Makedonia	12.40	−71.10	72.30	−27.56	87.00	0.46	106.20	74.67	54.50	153.49	6.00	185.71	338.40	7.87
Dytiki Makedonia	2.70	−56.45	10.60	−25.87	13.10	1.55	13.50	51.69	7.70	32.76	1.10	57.14	48.70	−0.20
Ipeiros	1.30	−76.79	9.20	−41.03	13.40	3.88	16.70	68.69	8.50	28.79	1.50	15.38	50.60	−2.50
Thessalia	8.70	−45.63	26.10	−27.70	34.10	7.23	40.30	77.53	26.20	109.60	4.60	24.32	140.00	14.01
Sterea Ellada	5.50	−60.99	20.50	−17.34	22.80	22.58	25.30	87.41	16.30	94.05	1.60	−5.88	92.00	13.44
Ionia Nisia	2.30	−37.84	6.70	−30.93	9.20	−1.08	10.00	36.99	7.20	56.52	1.40	−53.33	36.80	−2.13
Dytiki Ellada	10.10	−29.86	24.50	−21.97	28.60	8.33	30.30	56.99	19.40	81.31	2.00	122.22	114.90	11.45
Peloponnisos	4.10	−52.87	20.50	−19.29	26.60	1.14	32.30	53.81	19.60	66.10	3.60	24.14	106.70	11.03
Attiki	36.30	−62.11	168.40	−30.59	225.70	10.42	237.60	87.09	113.40	218.54	8.80	183.87	790.20	11.53
Voreio Aigaio	1.80	−52.63	8.00	3.90	9.30	75.47	10.20	161.54	6.00	122.22	1.20	33.33	36.50	50.21
Notio Aigaio	2.00	−74.36	12.70	−21.60	17.90	45.53	18.40	127.16	9.40	176.47	1.60	220.00	62.00	28.36
Kriti	4.20	−69.78	25.20	−26.74	35.60	23.61	35.00	62.79	19.50	53.54	3.20	−38.46	122.70	5.32

Figure 5 illustrates clusters of the female economically active population across Greece's 13 NUTS2 regions for 2021 and 2001. Anatoliki Makedonia–Thraki and Peloponnisos display strong high-value clustering in 2021 and 2001, respectively. The Low–High group includes Dytiki Makedonia, Ipeiros, Sterea Ellada, and the insular regions, indicating low populations surrounded by high values in 2021, while the High–Low group features Kentriki Makedonia, Thessalia, Dytiki Ellada, Attiki, Peloponnisos, and Kriti, with high populations surrounded by low values for the same year.

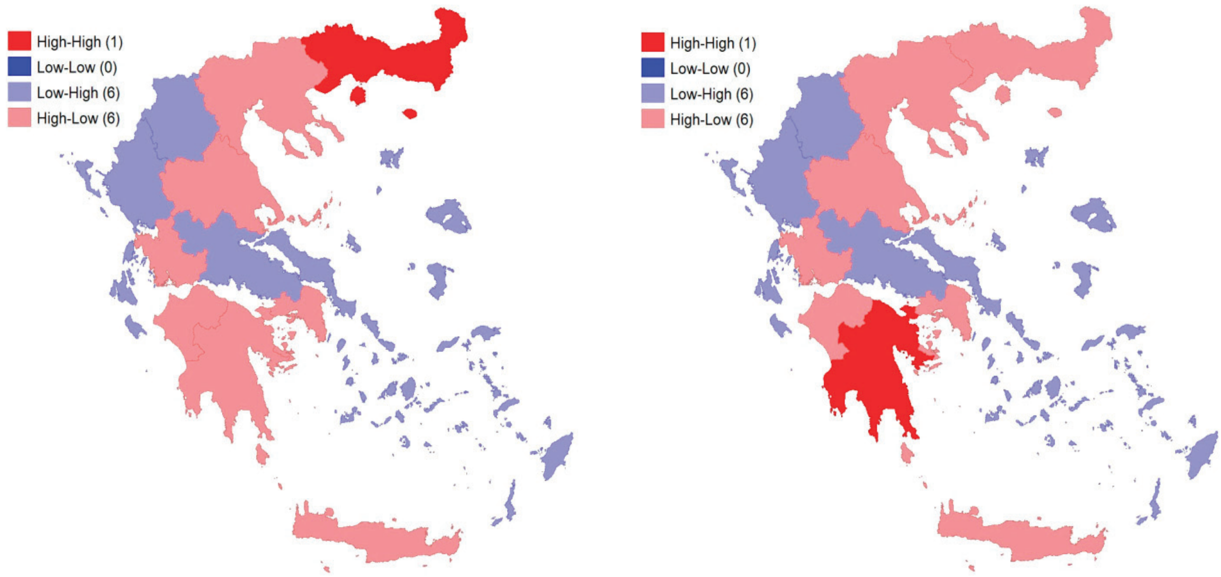

Figure 5. Cluster maps of female economically active population for 2021 and 2001.

The next maps picture the gross value added in Greek NUTS2 regions for 2021 and 2001 (Figure 6) to present a visual data on the economic performance of Greek regions. The next two charts display the percentage growth rate of gross value added for Greek NUTS2 regions between 2021 and 2001 (Figure 7) and the total gross value added for the examined economic branches in Greece for the years 2021 and 2001 (Figure 8) highlighting economic changes in regions and the branch-specific contributions.

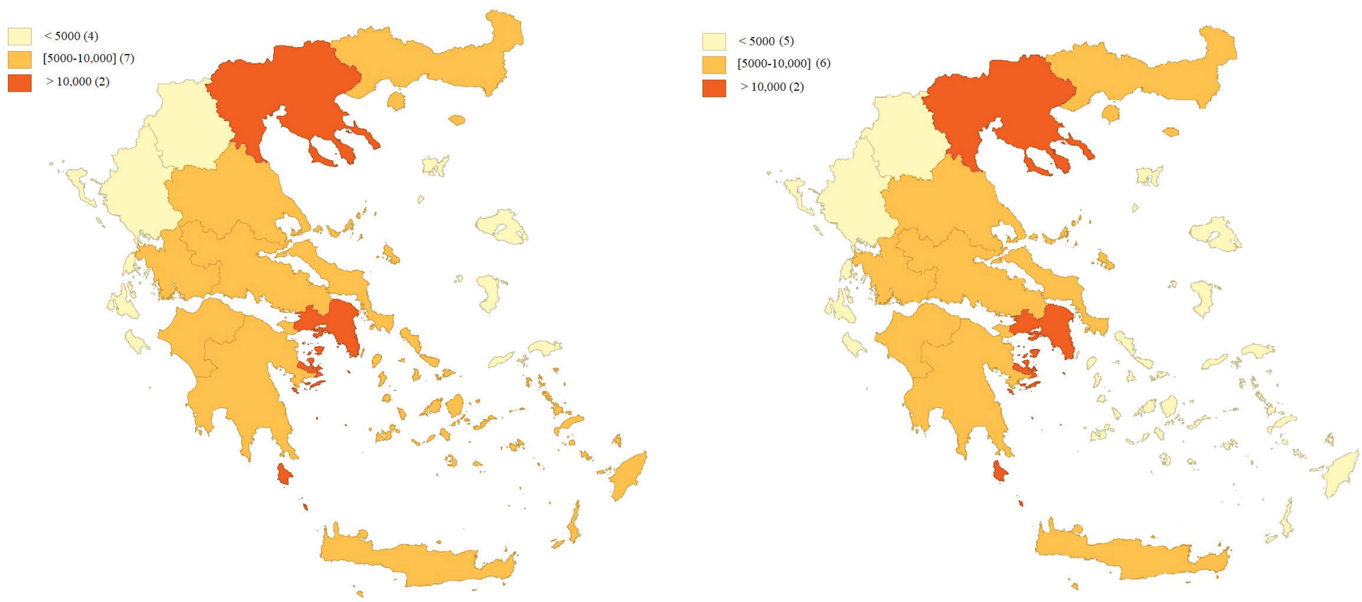

Figure 6. Gross value added in Greek NUTS2 regions for 2021 and 2001.

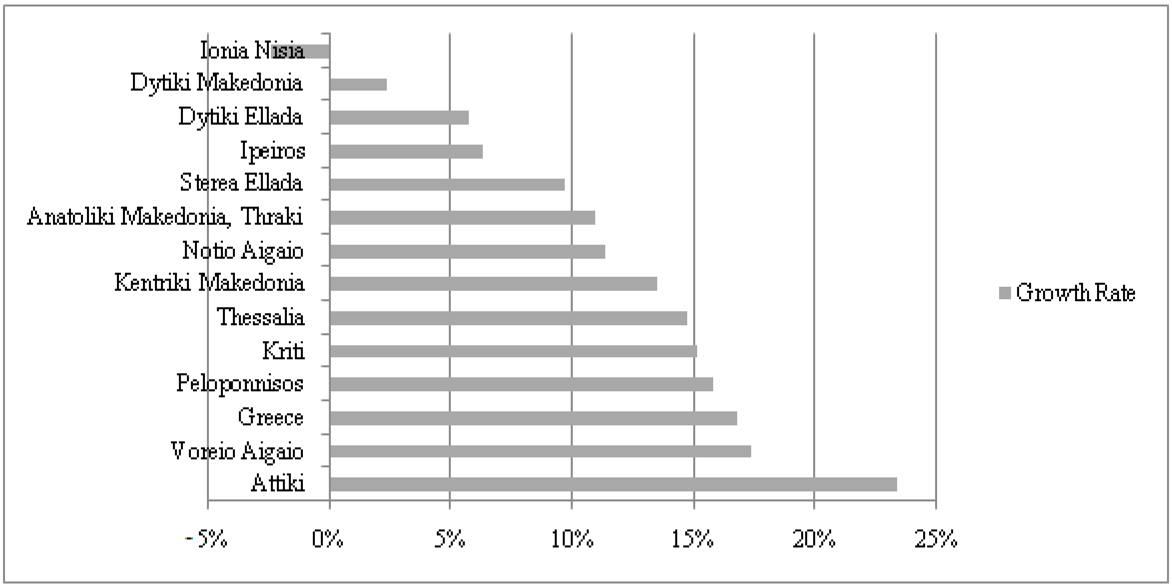

Figure 7. Percentage growth rate of gross value added in Greek NUTS2 regions, 2001–2021.

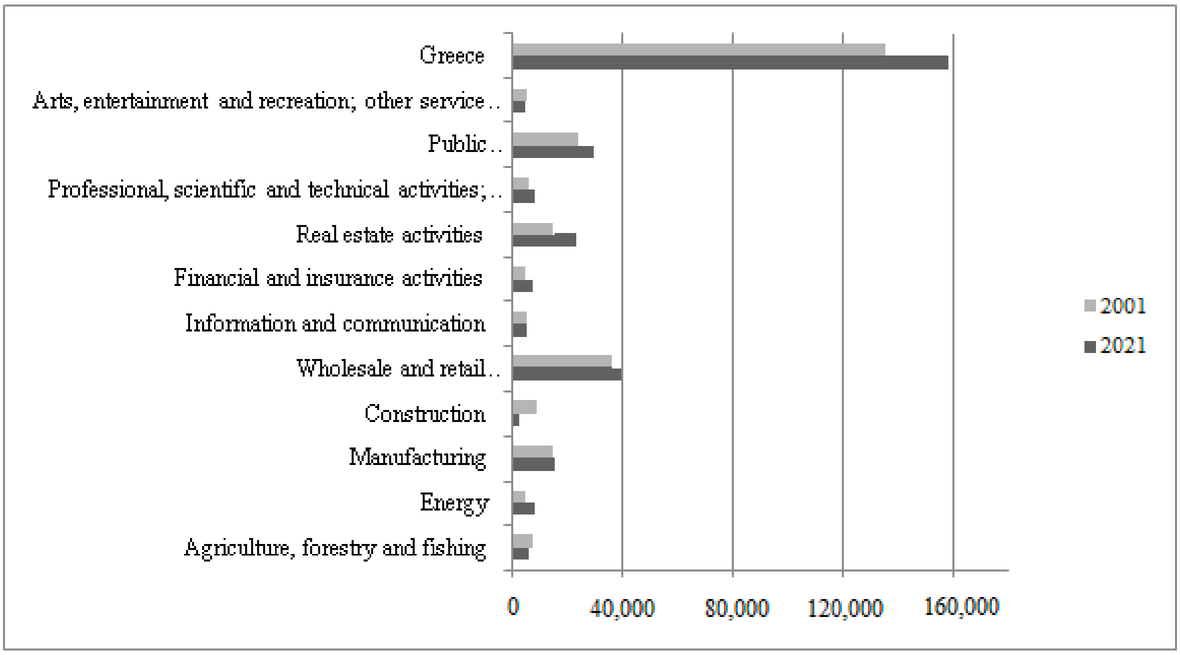

Figure 8. Total gross value added per economic branch, 2001 and 2021.

As shown in Figure 6, Attiki and Kentriki Makedonia (the two metropolitan regions of the country) lead with the highest gross value added in both years. In 2021, these two regions are followed by a group of regions including Anatoliki Makedonia–Thraki, Thessalia, Sterea Ellada, Dytiki Ellada, Peloponnisos, Notio Aigaio, and Kriti, each with a gross value added between 5000 and 10,000 million euros. The regions with the lowest gross value added, less than 5000 million euros, are Dytiki Makedonia, Ipeiros, Ionia Nisia, and Voreio Aigaio for the recent year.

Based on Figure 7, 12 out of 13 Greek regions show positive percentage growth rates between 2001 and 2021. Moreover, the regions of Attiki (23.36%) and Voreio Aigaio (17.31%) exhibit the highest growth rates, exceeding the national average of 16.75%. Only the insular region of Ionia Nisia illustrates a decline in growth rate (−2.44%).

According to Figure 8, the total gross value added increases in 2021 compared to 2001 in the Greek economy. The economic branch of "Wholesale and retail trade, transport, accommodation, and food service activities" has the highest gross value added compared to other economic branches for the most recent year. It is followed by the branches "Public administration, defence, education, human health, and social work activities", "Real estate activities", and "Manufacturing". Furthermore, these specific branches, along with the branches "Energy", "Information and communication", "Financial and insurance activities", and "Professional, scientific and technical activities; administrative and support service activities" increase their gross added value in 2021 compared to 2001. On the contrary, the economic branch of "Construction" has the lowest gross added value, a branch that, as shown in the diagram, has significantly decreased in gross added value compared to 2001. Other economic branches that exhibit a decrease in gross added value during the examined period are "Agriculture, forestry, and fishing" and "Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organisations and bodies".

The next table (Table 5) displays the location quotients, highlighting the degree of specialisation across Greek regions. Meanwhile, the following figures (Figures 9–11) depict cluster formation based on gross value added data to reveal spatial patterns of economic sectors through Univariate Local Moran's I, highlighting regional economic structures for 2021 and 2001.

The analysis presented in Table 5 shows that a considerable number of Greek regions specialised in the economic branch of "Agriculture, forestry and fishing". Especially, Thessalia, Dytiki Makedonia, Peloponnisos, Dytiki Ellada and Ipeiros display notable location quotients among the Greek regions for the recent year. Furthermore, Dytiki Makedonia shows the largest location quotients in "Energy" for both examined years, while the mainland region of Sterea Ellada displays the largest location quotients in the economic branch of "Manufacturing" for 2001 and 2021.

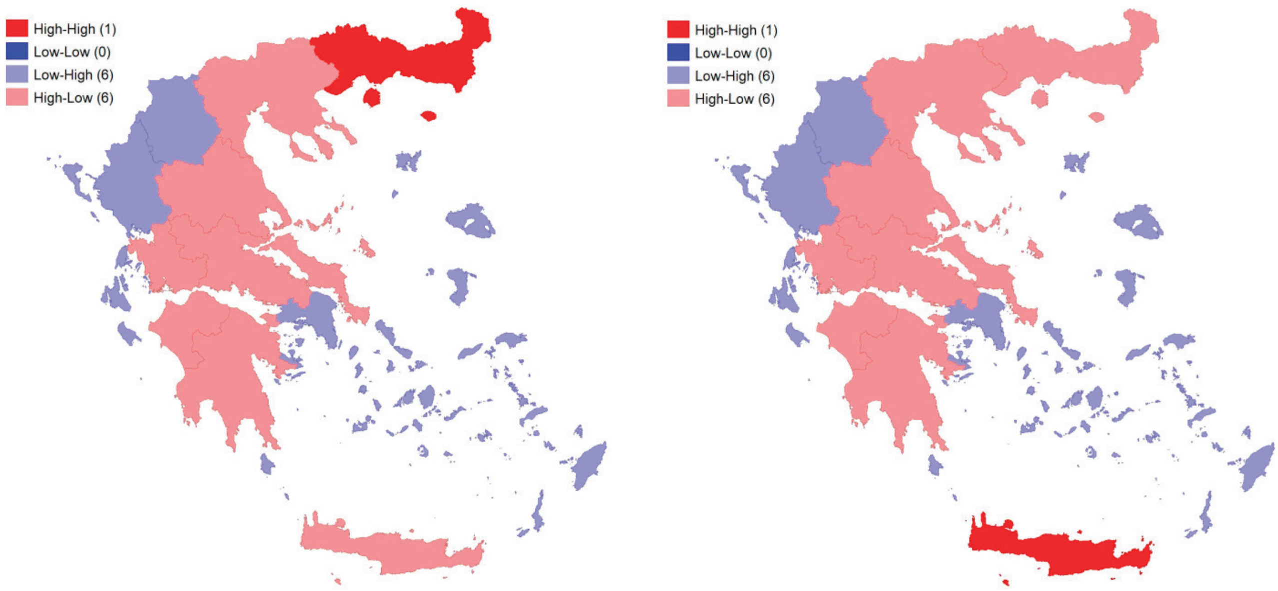

Figure 9. Cluster maps of "Primary sector" for 2021 and 2001.

Table 5. Location quotient per economic branch and Greek NUTS2 region, 2001 and 2021.

NUTS2	A		B		C		D		E		F		G		H		I		J		K	
	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001	2021	2001
Anatoliki Makedonia, Thraki	1.86	2.08	1.68	1.24	1.16	1.11	0.97	1.11	0.83	0.92	0.43	0.48	0.55	0.57	0.69	0.57	0.53	0.63	1.38	1.18	0.78	1.00
Kentriki Makedonia	1.48	1.44	0.69	0.75	1.31	1.32	1.03	0.86	1.04	1.03	0.54	0.53	0.62	0.73	0.79	0.73	0.70	0.87	1.20	1.04	1.05	1.20
Dytiki Makedonia	2.49	1.56	5.61	9.20	0.52	0.34	1.34	1.32	0.50	0.58	0.26	0.34	0.50	0.45	0.59	0.54	0.36	0.50	1.02	0.84	0.75	0.91
Ipeiros	2.21	1.96	0.98	1.08	0.84	0.61	1.77	1.46	0.91	0.95	0.36	0.43	0.65	0.57	0.89	0.81	0.54	0.58	1.31	1.29	0.83	0.90
Thessalia	3.22	2.32	0.50	0.57	1.41	1.14	1.10	0.92	0.78	0.92	0.24	0.38	0.50	0.55	0.75	0.76	0.53	0.65	1.33	1.16	0.93	1.18
Sterea Ellada	1.54	2.01	3.74	0.91	2.37	2.99	0.88	1.08	0.65	0.68	0.22	0.32	0.35	0.35	0.62	0.57	0.39	0.38	0.70	0.69	0.76	0.65
Ionia Nisia	0.89	0.90	0.46	0.42	0.25	0.20	1.30	0.93	1.84	1.96	0.28	0.37	0.44	0.41	1.03	0.79	0.71	0.52	0.77	0.78	1.16	0.95
Dytiki Ellada	2.22	2.39	1.20	0.71	0.89	0.83	1.26	1.39	0.89	0.97	0.55	0.60	0.52	0.58	0.95	0.87	0.58	0.53	1.19	1.01	1.12	0.93
Peloponnisos	2.24	2.12	2.62	1.36	1.33	1.49	1.24	1.07	0.77	1.17	0.32	0.52	0.47	0.52	0.94	0.91	0.37	0.54	0.85	1.05	1.11	1.05
Attiki	0.09	0.08	0.46	0.72	0.85	0.83	0.82	0.90	1.00	0.92	1.65	1.65	1.48	1.52	1.22	1.32	1.44	1.43	0.90	1.03	1.04	1.03
Voreio Aigaio	1.00	1.86	0.89	0.54	0.37	0.27	1.35	1.04	0.93	1.28	0.44	0.62	0.81	0.65	0.97	0.97	0.60	0.62	1.69	1.18	0.83	0.75
Notio Aigaio	0.55	0.58	0.99	1.24	0.23	0.23	1.62	1.28	1.94	1.94	0.26	0.34	0.52	0.48	0.81	0.70	0.77	0.50	0.74	0.72	0.82	0.73
Kriti	1.85	1.67	0.90	0.87	0.61	0.45	1.22	1.25	1.38	1.41	0.51	0.48	0.82	0.62	0.76	0.71	0.80	0.72	0.93	0.92	1.00	0.89

A: Agriculture, forestry and fishing, B: Energy, C: Manufacturing, D: Construction, E: Wholesale and retail trade, transport, accommodation and food service activities, F: Information and communication, G: Financial and insurance activities, H: Real estate activities, I: Professional, scientific and technical activities, administrative and support service activities, J: Public administration, defence, education, human health and social work activities, K: Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organisations and bodies.

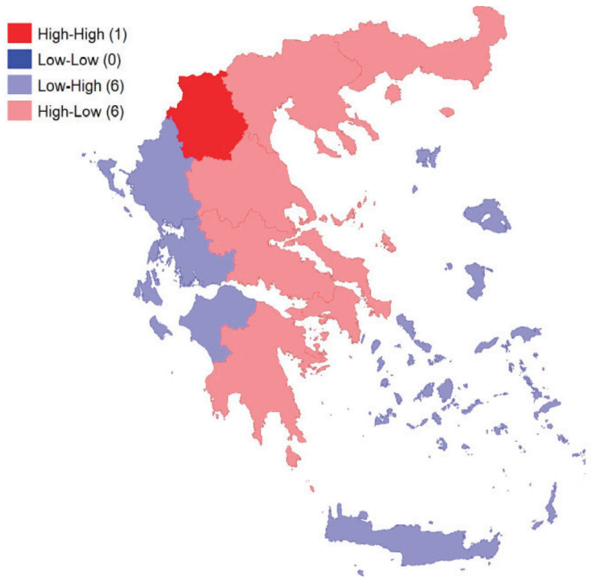

Figure 10. Cluster maps of "Secondary sector" for 2021 and 2001.

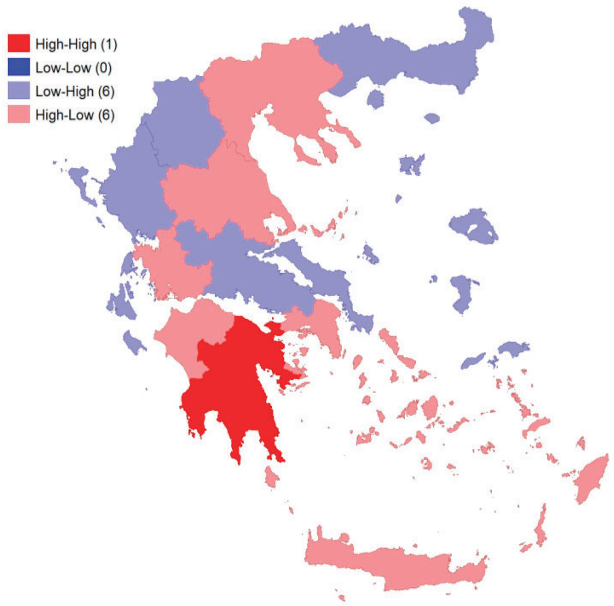

Figure 11. Cluster maps of "Tertiary sector" for 2021 and 2001.

In the economic branch "Construction", Ipeiros exhibits the highest location quotient. In the economic sector "Wholesale and retail trade, transport, accommodation and food service activities", the insular regions of Ionian Nisia and Notio Aigaio display the highest location quotients which are explained by the fact that they are significant tourist destinations. In the economic sectors "Information and communication", "Financial and insurance activities", "Real estate activities", and "Professional, scientific and technical activities; administrative and support service activities", the region specialising uniquely is Attiki. Finally, regarding the branch "Public administration, defence, education, human health and social work activities", Voreio Aigaio illustrates the highest location quotient for 2021, indicating a significant specialisation enhancement compared to 2001. Similarly, in the branch "Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organisations and bodies", another insular region, Ionian Nisia, displays the highest location quotient for 2021.

Figure 9 shows that Anatoliki Makedonia–Thraki and Kriti exhibit significant clustering of high gross value added in the "Primary sector" in 2021 and 2001, respectively. Dytiki Makedonia, Ipeiros, Attiki, and the insular regions are classified as Low–High, with low values surrounded by higher ones. Kentriki Makedonia, Thessalia, Sterea Ellada, Dytiki Ellada, Peloponnisos, and Kriti are High–Low, featuring high values surrounded by lower ones in 2021.

Figure 10 identifies Dytiki Makedonia as High–High, reflecting high gross value added in the "Secondary sector" among similarly high-value regions in 2021 and 2001. Ipeiros, Dytiki Ellada, and the insular regions are Low–High, with low values surrounded by higher ones. Anatoliki Makedonia–Thraki, Kentriki Makedonia, Thessalia, Sterea Ellada, Attiki, and Peloponnisos are High–Low, displaying strong values amidst regions with lower performance in 2021.

Figure 11 exhibits Peloponnisos as High–High, with high gross value added in the "Tertiary sector" surrounded by similar high-value regions for the recent year. Anatoliki Makedonia–Thraki, Dytiki Makedonia, Ipeiros, Sterea Ellada, Ionia Nisia and Voreio Aigaio are Low–High, indicating low values surrounded by higher ones. Kentriki Makedonia, Thessalia, Dytiki Ellada, Attiki, Notio Aigaio, and Kriti are High–Low, featuring strong values amidst regions with less impressive performance.

4. Discussion

The analysis reveals significant correlations between the economically active population and gross value added (GVA) across Greek NUTS2 regions for 2001 and 2021, reflected in near-perfect Pearson correlation coefficients of 0.987 for 2021 and 0.988 for 2001. These findings underscore the critical role of a vibrant workforce in driving regional economic performance, aligning with prior studies by Franklin (2012) and Lee and Shin (2021), which emphasise the influence of demographic characteristics on GDP growth. This robust relationship affirms the insights from Gómez and de Cos Pablo (2008), who highlighted the positive correlation between population dynamics and economic performance across various contexts. Spatial dependence is a notable aspect of the findings, indicated by the Spatial Lag Model (SLM) and Spatial Error Model (SEM), which reveal strong interdependencies between neighbouring regions. This supports Gómez and de Cos Pablo's (2008) assertion regarding how demographic transitions in one region can significantly affect economic outcomes in adjacent areas. In the context of the analysis, regions with higher economically active populations exert considerable influence on the economic activities of neighbouring regions, creating positive spillover effects. This dynamic is particularly evident in the metropolitan area of Attiki, which, as the primary urban hub, consistently exhibits the highest economically active population. The region's high concentration of people and economic activities reinforces the findings of Kurek (2011) and Kashnitsky et al. (2021), which suggest that demographic changes are shaped by unique regional characteristics and historical contexts, resulting in spatial disparities. The demographic data segmented by age groups reveals notable trends across the Greek regions. The 15 to 24 and 25 to 34 age groups generally experienced a decline in their economically active populations from 2001 to 2021. Conversely, the 45 to 54 and 55 to 64 age groups exhibited increases in their percentage growth rates. This aligns with findings from Franklin (2012) and Cheng et al. (2019), who explored the significant influence of ageing populations on regional economic outcomes. These shifts indicate a complex demographic landscape where younger populations are declining while older age cohorts are becoming more prominent, ultimately impacting the workforce composition and economic vitality of various regions. Examining spatial patterns highlights distinct distributions of economically active populations and their growth rates across different age groups and genders. The economically active population trends correlate with the location quotient analysis, reflecting regional economic specialisations. Regions such as Thessalia, Peloponnisos, and Dytiki Makedonia, which are primarily focused on the "primary sector," are facing population declines, signalling potential economic challenges. In contrast, Notio Aigaio, with high location quotients in tourism-related sectors, is experiencing significant workforce growth. This finding suggests that regions with diverse or thriving economic sectors are better positioned to retain or attract a larger workforce, while those with narrower specialisations may struggle to maintain their populations. The clustering of economically active populations, as illustrated in the Moran's I maps, indicates regions exhibiting similar demographic trends. This clustering reinforces the notion of regional specialisation and economic interdependence. Regions that neighbour those with high values in economically active populations and GVA demonstrate a high–high clustering effect based on median Local Moran's I. This dynamic suggests that regions with higher economically active populations stimulate economic activities and opportunities in surrounding areas, fostering a collaborative environment that attracts businesses, investments, and workforce migration. Notably, the metropolitan regions of Attiki and Kentriki Makedonia are key players in this interaction, influencing adjacent regions through the creation of economic spillover effects and increased demand for supporting services. These observations underline the importance of regional economic specialisation, as discussed by Lin et al. (2015), Dolls et al. (2019), and Okada (2020). The patterns indicate that successful regions tend to be those that develop diverse economic bases, allowing for resilience in the face of demographic changes and economic challenges. The sectoral analysis highlights significant specialisations, particularly in agriculture and tourism, with a marked decline in the construction sector. This decline aligns with the observations made by Cai and Stoyanov (2016) and Borda et al. (2023), who noted that demographic changes and an ageing labour force adversely affect sectoral efficiencies. The high gross value added in the "Wholesale and retail trade, transport, accommodation, and food service activities" sector illustrates a significant shift toward service-oriented economies. This trend echoes findings from Cheng et al. (2019), which noted similar patterns in urban versus rural areas in China. Such shifts imply that regions are increasingly moving away from traditional primary and secondary sectors toward more diversified service sectors, which may better accommodate the demands of an ageing population and evolving economic landscape. However, the limitations of this study warrant attention. The reliance on aggregated regional data may obscure localised variations and complexities inherent in demographic changes. While the spatial models reveal significant relationships, they do not account for all unobserved factors influencing economic performance, as highlighted by DiPasquale (2022). Consequently, future research should consider longitudinal studies that explore causal mechanisms linking demographic changes to economic outcomes, particularly regarding sectoral performance and income inequality, as noted by Dolls et al. (2019). In addition, more granular data at the NUTS3 level would enhance understanding of the nuances of demographic dynamics. By enabling policymakers to develop targeted interventions that address specific challenges and opportunities presented by ageing populations and regional economic disparities, this approach could lead to more effective policy solutions. Future investigations could benefit from incorporating finer spatial scales and additional demographic variables, such as educational attainment and migration patterns, to provide a more nuanced understanding of regional economic dynamics. Additionally, considering external factors, including policy impacts and labour market conditions, would enrich the analysis of demographic–economic interactions. In conclusion, these findings contribute to a broader understanding of how demographic changes influence regional economic performance, emphasising the complex interplay between population dynamics, regional specialisation, and economic outcomes. As regions continue to navigate the challenges posed by demographic transitions, it becomes increasingly essential to develop policies that promote sustainable economic growth while addressing the specific needs of diverse populations. This comprehensive approach will ultimately facilitate the creation of resilient and adaptable economies capable of thriving in an ever-changing demographic landscape.

5. Conclusions

In summary, the results highlight significant spatial and temporal variations in the economically active population and gross value added (GVA) across Greek NUTS2 regions. A strong positive correlation exists between the economically active population and GVA in both 2021 and 2001, as reflected in the near-perfect Pearson correlation coefficients. This emphasises the crucial role of a robust workforce in driving regional economic performance. The spatial regression models further underscore the importance of spatial dependencies, with the Spatial Lag Model (SLM) and Spatial Error Model (SEM) revealing significant spatial autocorrelation. The SEM provides a slightly better fit, suggesting that unobserved spatial effects significantly influence GVA distribution. The demographic analysis demonstrates a decline in Greece's total population between 2001 and 2021, with male populations declining more steeply than female populations. Despite this, Attiki, the country's metropolitan hub, consistently leads in both total and gender-specific economically active populations, followed by Kentriki Makedonia. Regions such as Voreio Aigaio, Ionia Nisia, and Ipeiros typically show the lowest economically active populations. However, Voreio Aigaio displays notable growth, especially among older age groups, highlighting regional disparities in demographic trends. Spatial clustering of economically active populations and GVA reveals regional economic patterns. High-value regions, such as Attiki and Kentriki Makedonia, are surrounded by lower-performing areas, reflecting disparities in economic development. Furthermore, the analysis of sector-specific GVA shows that regions like Thessalia and Dytiki Makedonia specialise in agriculture and energy, while Attiki dominates in services like finance and communication. In conclusion, Greece's regional economies exhibit substantial spatial dependencies, with metropolitan regions leading in economic performance. Peripheral and insular regions, although lagging in overall economic activity, show promising growth in certain sectors and demographic groups. Accounting for spatial autocorrelation in regional economic models is crucial for accurate analysis and policy planning aimed at fostering balanced regional development.

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References

Anselin, Luc. 1988. *Spatial Econometrics: Methods and Models*. Dordrecht: Kluwer Academic.

Anselin, Luc. 1995. Local indicators of spatial association—LISA. *Geographical Analysis* 27: 93–115. [CrossRef]

Bode, Eckhardt, Dirk Dohse, and Ulrich Stolzenburg. 2023. Aging and regional productivity growth in Germany. *Review of Regional Research* 43: 409–32. [CrossRef] [PubMed]

Borda, Áron József, Sárvári Balázs, and Jeremiás Máté Balogh. 2023. Generation change in agriculture: A systematic review of the literature. *Economies* 11: 129. [CrossRef]

Cai, Jie, and Andrey Stoyanov. 2016. Population aging and comparative advantage. *Journal of International Economics* 102: 1–21. [CrossRef]

Chen, Chan, Jie Li, and Jian Huang. 2022. Spatial–temporal patterns of population aging in rural China. *International Journal of Environmental Research and Public Health* 19: 15631. [CrossRef]

Cheng, Yang, Siyao Gao, Shuai Li, Yuchao Zhang, and Mark Rosenberg. 2019. Understanding the spatial disparities and vulnerability of population aging in China. *Asia & Pasific Policy Studies* 6: 73–89.

Chung, Seunghun, and Oudom Hean. 2023. The effects of aging populations on U.S. communities. *Economies* 11: 277. [CrossRef]
Cuadrado-Roura, Juan R., Ron Martin, and Andrés Rodríguez-Pose. 2016. The economic crisis in Europe: Urban and regional consequences. *Cambridge Journal of Regions, Economy and Society* 9: 3–11. [CrossRef]
Cuaresma, Jesus Crespo, Elke Loichinger, and Gallina A. Vincelette. 2016. Aging and income convergence in Europe: A survey of the literature and insights from a demographic projection exercise. *Economic Systems* 40: 4–17. [CrossRef]
Danko, Joseph J., III, and Dean M. Hanink. 2018. Beyond the obvious: A comparison of some demographic changes across selected shrinking and growing cities in the United States from 1990 to 2010. *Population, Space and Place* 24: 21–36. [CrossRef]
DiPasquale, Giacomo. 2022. The effects of international immigration on inequality in host countries: The case of Italy. *Journal of International Migration and Integration* 23: 1793–1824. [CrossRef]
Dolls, Mathias, Karina Doorley, Alari Paulus, Hilmar Schneider, and Eric Sommer. 2019. Demographic change and the European income distribution. *The Journal of Economic Inequality* 17: 337–57. [CrossRef]
Eurostat. 2024a. Economically Active Population by Sex, Age and NUTS 2 Regions. Available online: https://ec.europa.eu/eurostat (accessed on 5 April 2024).
Eurostat. 2024b. Gross Value Added at Basic Prices by NUTS 2 Regions. Available online: https://ec.europa.eu/eurostat (accessed on 6 April 2024).
Eurostat. 2024c. Population on 1 January by Age Group, Sex and NUTS 2 Region. Available online: https://ec.europa.eu/eurostat (accessed on 10 April 2024).
Feng, Jie, Ganlin Hong, Wenrong Qian, Ruifa Hu, and Guanming Shi. 2020. Aging in China: An international and domestic comparative study. *Sustainability* 12: 5086. [CrossRef]
Franklin, Rachel S. 2012. An examination of the geography of population composition and change in the United States, 2000–2010: Insights from geographical indices and a shift–share analysis. *Population, Space and Place* 20: 18–36. [CrossRef] [PubMed]
Göbel, Christian, and Thomas Zwick. 2012. Age and productivity: Sector differences. *De Economist* 160: 35–57. [CrossRef]
Gómez, Rafael, and Hernández de Cos Pablo. 2008. Does population ageing promote faster economic growth? *Review of Income and Wealth* 54: 350–72. [CrossRef]
Han, Joohun, and Chanjin Chung. 2021. Impact of aging and underemployment on income disparity between agricultural and non-agricultural households. *Sustainability* 13: 11737. [CrossRef]
Hirono, Makoto. 2021. Demographic change, human capital accumulation, and sectoral employment. *The Journal of Economics* 132: 165–85. [CrossRef]
Isserman, Andrew. 1977. The location quotient approach to estimating regional economic impacts. *Journal of the American Planning Association* 43: 33–41. [CrossRef]
Iwasaki, Yukiya. 2021. Shrinkage of regional cities in Japan: Analysis of changes in densely inhabited districts. *Cities* 113: 103168. [CrossRef]
Jayawardhana, Thaveesha, Ruwan Jayathilaka, Thamasha Nimnadi, Sachini Anuththara, Ridhmi Karadanaarachchi, Kethaka Galappaththi, and Thanuja Dharmasena. 2023. The cost of aging: Economic growth perspectives for Europe. *PLoS ONE* 18: e0287207. [CrossRef] [PubMed]
Kashnitsky, Ilya, Joop de Beer, and Leo van Wissen. 2021. Unequally ageing regions of Europe: Exploring the role of urbanisation. *Population Studies* 75: 221–37. [CrossRef] [PubMed]
Kim, Eun Jung, Myung-Yeon Kim, and Hyunjung Kim. 2020. Spatio-temporal trend of aging regions and their neighborhood environment: Findings from Daegu Metropolitan City, Korea. *Sustainability* 12: 1218. [CrossRef]
Kurek, Slawomir. 2011. Double transitions? Regional patterns of population ageing in Poland. *Geografiska Annaler: Series B, Human Geography* 93: 163–84. [CrossRef]
Lee, Hyun-hoon, and Kwanho Shin. 2021. Decomposing effects of population aging on economic growth in OECD Countries. *Asian Economic Papers* 20: 138–59. [CrossRef]
Lin, Chun-Hung A., Suchandra Lahiri, and Ching-Po Hsu. 2015. Population aging and regional income inequality in Taiwan: A spatial dimension. *Social Indicators Research* 122: 757–77. [CrossRef]
Liu, Jian, Chao Zhang, Ruifa Hu, Xiaoke Zhu, and Jinyang Cai. 2019. Aging of agricultural labor force and technical efficiency in tea production: Evidence from Meitan county, China. *Sustainability* 11: 6246. [CrossRef]
Mahlberg, Bernhard, Inga Freund, Jesús Crespo Cuaresma, and Alexia Prskawetz. 2013. The age-productivity pattern: Do location and sector affiliation matter? *The Journal of the Economics of Ageing* 1–2: 72–82. [CrossRef]
Malmberg, Anders, Bo Malmberg, and Peter Maskell. 2023. Population age structure—An underlying driver of national, regional and urban economic development. *ZFW – Advances in Economic Geography* 67: 217–33. [CrossRef]
Mariscal-de-Gante, Álvaro, Amaia Palencia-Esteban, Sara Grubanov-Boskovic, and Enrique Fernández-Macías. 2023. *Feminisation, Ageing and Occupational Change in Europe in the Last 25 Years*. JRC Working Papers Series on Labour, Education and Technology, No. 2023/04. Seville: European Commission, Joint Research Centre (JRC).
OECD. 2020. *Territorial Review: Regional Policy for Greece Post 2020*. Athens: OECD.
Okada, Kohei. 2020. Dynamic analysis of demographic change and human capital accumulation in an R&D-based growth model. *The Journal of Economics* 130: 225–48.
Papapetrou, Evangelia, and Pinelopi Tsalaporta. 2020. The impact of population aging in rich countries: What's the future? *Journal of Policy Modeling* 42: 77–95. [CrossRef]

Peterson, E. Wesley F. 2017. The Role of Population in Economic Growth. *SAGE Open* 7: 1–15. [CrossRef]
Santos, Eleonora. 2024. Shifting demographics and economic performance: Unraveling the influence of population aging on GDP dynamics and regional inequalities. *Journal of Economic Analysis* 3: 118–28. [CrossRef]
Seok, Jun Ho, Hanpil Moon, Gwan Seon Kim, and Michael R. Reed. 2018. Is aging the important factor for sustainable agricultural development in Korea? Evidence from the relationship between aging and farm technical efficiency. *Sustainability* 10: 2137.
Shen, Danhong, Haimeng Liang, and Wangfang Shi. 2023. Rural population aging, capital deepening, and agricultural labor productivity. *Sustainability* 15: 8331. [CrossRef]
Shiode, Narushige, Masatoshi Morita, Shino Shiode, and Kei-ichi Okunuki. 2014. Urban and rural geographies of aging: A local spatial correlation analysis of aging population measures. *Urban Geography* 35: 608–28. [CrossRef]
Siliverstovs, Boriss, Konstantin. A. Kholodilin, and Ulrich Thiessen. 2011. Does aging influence structural change? Evidence from panel data. *Economic Systems* 35: 244–60. [CrossRef]
Song, Mengfei, Qiuyi Wu, and Honghui Zhu. 2024. Could the aging of the rural population boost green agricultural total factor productivity? Evidence from China. *Sustainability* 16: 6117. [CrossRef]
Wessel, Terje, Magnusson Lena Turner, and Viggo Nordvik. 2018. Population dynamics and ethnic geographies in Oslo: The impact of migration and natural demographic change on ethnic composition and segregation. *Journal of Housing and the Built Environment* 33: 789–805. [CrossRef]
Xu, Fan, Yongming Huang, and Qiang Wang. 2022. Aging industries in the regional economy: How to support an aging China? *Land* 11: 2096. [CrossRef]
Zhang, Hui, Jing Li, and Tianshu Quan. 2023. Strengthening or weakening: The impact of an aging rural workforce on agricultural economic resilience in China. *Agriculture* 13: 1436. [CrossRef]
Zhang, Mingzhi, Chao Chen, Xiangyu Zhou, Xinpei Wang, Bowen Wang, Fuying Huan, and Jianxu Liu. 2024. The impact of accelerating population aging on service industry development: Evidence from China. *PLoS ONE* 19: e0296623. [CrossRef] [PubMed]

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Accessibility and Older and Foreign Populations: Exploring Local Spatial Heterogeneities across Italy

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Abstract: The interplay between accessibility and population change is a relatively new subject in Italian academic research. Along with social and economic factors such as regional economic prosperity, the ease of movement inside and outside an area can play a pivotal role in shaping population dynamics. This study seeks to explore the spatial distribution and spatial relationships of three indicators, including one related to real accessibility (RAI) and two others related, respectively, to the shares of the older population (SOP) and of the foreign population (SFP). An exploratory spatial data analysis is, therefore, conducted at the local level using Italian municipalities as the statistical units for the empirical analysis. Local univariate spatial autocorrelation analysis is used together with a regression analysis based on ordinary least squares (OLS) and geographically weighted regression (GWR) models. The results provide valuable insights into the local heterogeneity that characterizes the distribution of each indicator and the local relationship between them, highlighting the importance of thinking locally in quantitative social sciences.

Keywords: local demography; spatial analysis; territorial imbalances; foreign population; older population; accessibility; municipalities; Italy

1. Introduction

In Italy, demographic dynamics and behaviors, coupled with socio-economic phenomena, have long followed different trends and characteristics according to the geographic contexts of reference (Billari and Tomassini 2021). Significant and deep-rooted territorial imbalances over time have affected many parts of the country—mountainous regions versus coastal areas, inland versus central areas, and rural versus urban and metropolitan areas—undermining the nation's territorial and social cohesion (Barca 2019; Annunziata et al. 2024; Campagnucci and Morettini 2024).

These differences are amplified at the local level, occurring within a macro framework that has traditionally been defined by the so-called north–south divide. This division juxtaposes the economically more dynamic, more industrialized, and more urbanized north with the south, which is more agricultural, less urbanized, and more vulnerable and fragile in socio-economic terms (Salvati 2014; Armenise et al. 2022).

Even at a demographic level, these differences are persistent and deeply rooted to the point that they have recently been defined, within the framework of Italian demographic exceptionalism, as true spatial inequalities (Benassi et al. 2021a). The causes of such inequalities are multiple and complex, originating from Italy's very demographic history (Rosina and Impicciatore 2022), as well as from the particularity of its geography and geomorphology, characterized by a pronounced heterogeneity and a multitude of small, often isolated, marginal and depopulated municipalities (Golini et al. 2000; Viesti 2021; Benassi et al. 2024)

In this context, the level of transport infrastructure and, more specifically, land accessibility of the different local contexts becomes a potent force in shaping the overall dynamics and the multiple challenges that territories face, including those related to economic and demographic growth/decline (Vickerman et al. 1999; Shelukdov et al. 2020). Indeed, remote areas or inner areas—that are very often less accessible—are particularly susceptible to poverty, social exclusions, and depopulation (Benassi et al. 2021a; Panagiotopoulos and Kaliampakos 2024).

The absence of adequate health and education infrastructure is a key factor in deterring young people from settling in these regions and, at the same time, acts as a push factor for those who already reside there (La Bianca and Navarro Valverde 2019; Staniscia and Benassi 2018; Muti 2023). This is why regional development policies often aim to mitigate spatial disparities through the enhancement of transport infrastructure, although with variable results (Panagiotopoulos and Kaliampakos 2024)

Italy, from this point of view, is an example of extreme interest. In fact, even from the perspective of accessibility, the gaps are relevant both between different macro-territorial contexts (with the north generally being more accessible than the south) and especially within these contexts (Campagnucci and Morettini 2024). These inequalities have significant repercussions on demographic dynamics, particularly on depopulation processes, as shown in several empirical studies related to other southern European countries (Panagiotopoulos and Kaliampakos 2024; Melo et al. 2022; Rodríguez-Rodríguez and Larrubia Vargas 2022; Alamá-Sabater et al. 2019, 2021; Sánchez-Mateos and Pulpón 2021). Although it has also been observed in Italy that the presence of essential services closely linked to accessibility—such as elementary schools—are determinants of demographic growth/decline processes (Benassi et al. 2023), to the best of our knowledge, studies that have so far correlated the accessibility of territorial contexts with their demographic characteristics and/or demographic dynamics at a local scale are almost absent. This is also due to the limited availability of accessibility indicators provided by official statistics (Chiocchini and Cruciani 2009) up until now.

Based on these premises, the main purpose here is to investigate—at the local scale for Italy—the spatial dimension of land accessibility, the share of the older population, and the share of the foreign population. These last two indicators are closely linked to the demographic phenomenon generally associated with accessibility, namely depopulation. In fact, depopulation is often observed as a self-perpetuating process (Reynaud et al. 2020) that is intimately linked to aging (Reynaud and Miccoli 2023), but also as something that can at least be slowed down by foreign immigration (Gesano and Strozza 2011).

Understanding how the accessibility of local contexts correlates with the aging process and foreign presence (i.e., international migration) is, therefore, an important issue. Indeed, aging and foreign presence have a significant impact on population growth and age structure, serving as focal points of interest in demographic and socio-economic phenomena (Harper 2014; Reitz 2002). Moreover, both the older and foreign populations exhibit specific geographical distributions related to the different socio-economic characteristics of the local host contexts, posing important challenges in terms of spatial planning and regional development (Reynaud and Miccoli 2023; Strozza et al. 2016; Tragaki and Rovolis 2014). In this regard, it is useful to recall that aging and foreign presence (international migrations) are two of the most significant demographic processes in the current Italian demographic landscape (Billari and Tomassini 2021).

Empirically, we focused on the spatial distributions of an accessibility indicator and two demographic indicators related to aging and foreign presence. The aims of the paper are (i) to evaluate the existence of spatial patterns in the geographical distribution of these three indicators and (ii) to measure the relationships—also from a spatial perspective—between accessibility and the degree of aging and between accessibility and foreign presence.

The quantitative analysis is composed of two parts. The first part is devoted to the analysis of the spatial distribution of the ad hoc indicator of land accessibility (real accessibility index, RAI) and two demographic indicators related to the process of aging and foreign presence, namely, the share of the older population (SOP) and the share of the foreign population (SFP). The second part of the paper involves an exploratory spatial data analysis, whose first step consists of a local spatial autocorrelation analysis. The aim is to understand whether or not the geographic distribution of the indicators is clustered, and if so, where local clusters (hot and cold spots) are located. The second step employs geographically weighted regression (GWR) and ordinary least squares (OLS) models to analyze the relationship between the indicators, aiming to understand the overall and local impact of the RAI on SOP and SFP individually.

The results show that the aging process and foreign immigration are associated with the level of accessibility. This exhibits a negative relationship with the proportion of older people, which implies that depopulated and/or aging areas are those in which accessibility is worse. On the contrary, the relationship between accessibility and the proportion of the foreign population is positive, which means that the more accessible areas are also more dynamic and display a greater attractiveness for this population group.

These results hold at the global level, while locally, more different situations arise, underlying something that has been recently addressed by other studies on accessibility and rural depopulation (Panagiotopoulos and Kaliampakos 2024). Although improving accessibility also plays a key role in relation to aging and foreign immigration, spatial inequalities can only be addressed through appropriate locally tailored policies (Iammarino et al. 2019). This is something expected, since in a European context characterized by persistent differences in regional populations (Rees et al. 2012), the relevance of spatially oriented policies is crucial (Muti 2023).

Despite the efforts required to foster social cohesion within the territories of the European Union, some contexts are often left behind in terms of economic growth, and others also appear in demographic decline. Inadequate accessibility, in terms of connecting infrastructures, may be a determining factor in this process.

The rest of the paper is structured as follows. Section 2 outlines the theoretical background and reviews the literature. Section 3 presents the data and methods, and Section 4 introduces the results. Section 5 contains the discussion and, finally, Section 6 holds our preliminary conclusions.

Appendix A contains several maps of Italy's administrative divisions to help readers better understand the analysis. There is also a map of the urban–rural divide based on the degree of urbanization (OECD et al. 2021).

2. Theoretical Background and Literature Review

In this section, we provide an overview of the concept of accessibility and the existing approaches for its measurement (Section 2.1), the relationships between accessibility, population change, and economic growth (Section 2.2), and finally, the role of spatial heterogeneity in influencing the connections between accessibility and population dynamics (Section 2.3).

2.1. Accessibility: Concept and Measures

The theoretical background on accessibility identifies two primary components, namely the transport network and land use (Geurs and van Wee 2004; Stepniak and Rosik 2018).

The transport network refers to the concepts of friction or facilitation in mobility, encompassing the availability of services provided by the transport system, which includes the ease or difficulty of journeying between two points. The transport network is therefore directly related to the provision and characteristics of the local mobility infrastructure (Geurs and Ritsema van Eck 2001). It may be viewed as a direct reflection of a territory's degree of accessibility, which is intrinsically linked to the presence or absence of connecting infrastructures (Handy and Niemeier 1997), being closely associated with factors such as the physical development of infrastructure, deterrence or impedance (Moya-Gómez et al. 2018), and transportation policy, such road tolls (Solé-Ribalta et al. 2018).

The component of land use concerns the spatial distribution of accessibility. It describes the spatial attributes of supply and demand for connecting infrastructures, the spatial characterization of related activities, and their relationships (Geurs and Ritsema van Eck 2001). It also includes the role of accessible destinations from a spatial perspective (Vickerman 1974; Caschili et al. 2015). The spatial distribution of population change, including some demographic phenomena, such as aging and foreign presence, can be considered within the land-use component related to the accessibility issue. Indeed, a more complex and holistic definition of accessibility requires further elements, such as its role in residential land-use patterns (Hansen 1959), the ease with which a specific destination can be reached (Dalvi and Martin 1976), and the benefits derived from the transportation network. Accessibility is a potential driver of opportunities, particularly in its association with the efficiency of the transport system, which is crucial to reducing the spatial frictions associated with movement (De Montis and Reggiani 2012; Patuelli et al. 2007).

The definition of accessibility is, therefore, based on the assumption that a territory's appeal (relating to various aspects of the land-use component) increases in step with a reduction in physical distance, travel time, and the cost associated with the transport network (Stepniak and Rosik 2018). This might imply that regions with more efficient access to various locations should be more attractive and competitive, including in demographic terms, than isolated areas (Benassi et al. 2021b).

Empirically, the measurement of accessibility poses challenges. The approach commonly used involves evaluating the local transport system. In this vein, three categories are typically assessed, including (1) isochrones, based on the number of destinations according to travel time/physical distance/costs from a given starting point; (2) gravity-based models, based on a penalty assigned to more isolated destinations; and (3) individual-level models, grounded in individual utility (Handy and Niemeier 1997).

A more recent classification of accessibility measures suggests a different point of view depending on the object of observation and involves the following: (1) infrastructure-based measures, based on the observed performance of the infrastructure; (2) activity-based measures, based on the number of activities in which, even potentially, individuals may participate given time and space constraints; (3) utility-based measures, based on the utility people derive from reaching specific locations; and (4) individual-based measures, related to land-use and transportation systems allowing people to travel (Geurs and Ritsema van Eck 2001; Geurs and van Wee 2004; Karou and Hull 2014).

In this paper, as detailed in Section 3 Methodology, to which we refer for a more analytical view, we used a revised version of the accessibility indicator released by the Italian National Institute of Statistics (ISTAT) in December 2023.

2.2. On the Role of Accessibility in Economic and Demographic Change

Although numerous nuances exist regarding the concept of accessibility, its critical role in shaping the overall dynamics of local development is widely recognized. Two regional economic theories clearly describe the impact that varying degrees of accessibility have on development: growth pole theory and location theory.

Growth pole theory revolves around the concept of a "growth fulcrum", which is the existence of a center capable of exerting attraction upon surrounding areas. The core concept is that a specific location, typically urban, interacts with its surrounding areas through economies of scale and agglomeration, rebalancing development levels between these areas (Darwent 1969).

In turn, location theory asserts that the decisions firms and individuals make on their deployment are influenced by choices of cost minimization and demand maximization. The transport network, therefore, serves as a facilitator of relationships and flows between central hubs and their surrounding areas; it may, however, become a barrier when the transport infrastructure is deficient (Thompson and Bawden 1992; Voss and Chi 2006).

As changes in accessibility could lead to changes in local economic conditions (Berechman and Paaswell 2001; Ozbay et al. 2006), accessibility also influences population change

(Alamá-Sabater et al. 2019). According to a demographic approach, population change involves the interplay between the two components of natural change (i.e., births and deaths) and migration. The increasing decline in births is leading many territories, particularly those in rural areas, toward a continuous and inevitable process of depopulation (Alamá-Sabater et al. 2019; Melo et al. 2022; Reynaud et al. 2020). From a theoretical perspective, the impact of accessibility on population change has been explored through various models, including the general equilibrium model of household location choices (Roback 1982). In this model, transport costs are central to individual location decisions, as some households generally prefer locations with affordable property and easy access to urban amenities.

The role of the infrastructure system in population variations can also be understood through the lens of neo-classical growth theory. This theory posits that the combination of land (rural–suburban), capital (infrastructure systems), and labor (wages) (as inputs into production function) predicts that, as the transport network expands, the economic and social centrality of a region increases, potentially leading to (positive) population changes. Similarly, the facilitator role of the infrastructure system is a crucial aspect in the central place theory, whereby transport networks serve as vectors for relationships and flows between individuals across different locations, typically facilitating movement between a central hub and its surrounding regions (Thompson and Bawden 1992).

A large body of the literature has traditionally explored the factors, such as the presence of large cities, regional migration, economic growth, and sundry facets of quality of life and well-being, as elements that influence people's inclination to settle in a particular location (Glaeser et al. 1995; Graves 1983; Chi and Marcouiller 2009). Most of this research reports that greater accessibility, particularly in terms of transportation infrastructures, positively influences an area's economic growth by generating positive externalities for local firms (Berechman and Paaswell 2001), increasing employment in the region (Ozbay et al. 2006), and reducing commuting times, thereby enhancing the work–life balance (Van den Heuvel et al. 2014). Following this line, from a macro approach, many studies have investigated the correlation between the degrees of accessibility and economic indicators, such as the marginal effect on the price of commodities or GDP (Gutiérrez et al. 2010; Karou and Hull 2014). These studies underscore the overall positive effect that an increase in accessibility may have on a region's macroeconomic growth.

Recently, some studies have incorporated the concept of spatial dependence as an additional factor contributing to population change (Lundberg 2006; Delfmann 2014; Costa da Silva Firmino et al. 2017).

Chi (2010) has used an integrated spatial regression approach to investigate the impact of highway expansion on the population in Wisconsin, finding a difference among rural, urban, and suburban areas. Highway expansion triggers population flows, especially in suburban areas where the direct effect on demography is supported by the ease of commuting to urban areas and the lower cost of housing.

Melo et al. (2022) have explored the role of road accessibility in population changes in Portugal, finding that the decline in population is not simply explained by changes in accessibility: depopulation is explained mainly by demographic and economic factors, such as an uncompetitive job market. This study finds that enhancing accessibility seems to have the potential to reverse the progressive decline of rural territories by, for instance, offsetting the increasing number of individuals aged over 65 or the scarcity of those with higher education.

Focusing on aging as a pivotal demographic process in depopulation, Alamá-Sabater et al. (2019) have used an exploratory spatial data analysis to explore the issue in the hinterland of the Spanish region of Valencia. They consider specific territorial factors, such as the degree of accessibility, public infrastructures, and economic prosperity, while shedding light on the role played by the aging rate in the transition towards depopulation. Their study reveals that the lack of accessibility to rural areas is associated with a higher risk of population loss. Interestingly, the authors also find that the concept of rural depopulation cannot be understood solely at the municipal level but requires an understanding of the spatial interdependencies between a territory and its surroundings.

In sum, while the seminal literature on the relationship between accessibility and population change generally reports linear results, some local-level studies find significant heterogeneity due to an area's idiosyncrasies, which include local growth characteristics, environmental and natural resources, and land use and related development (Cardille et al. 2001), which may vary spatially across different territories (Partridge et al. 2008).

Closely linked to potential population change, especially at the local level, is the presence of a migrant population (Bagavos 2022), as new arrivals tend to settle within specific ethnic enclaves to enjoy the support of other non-natives.

Numerous studies have explored the settlement patterns of immigrants in both the United States and Europe (Hiebert 2000; Lo et al. 2011). Some of these investigations have revealed robust spatial correlations between migrant settlement trends and suburbanization (Kneebone and Garr 2010; Ehrenhalt 2012; Farrell 2016). Location decisions are often influenced by socioeconomic factors and the availability of affordable housing (Allen et al. 2021), with a strong spatial correlation between settlement and the concentration of poverty in urban areas (Kazemipur and Halli 2000; Burnley 2002).

Only a limited body of research has examined the relationship between transport accessibility and the presence of migrants. Existing research has linked restricted accessibility to greater difficulties in accessing supermarkets, schools, language classes, and healthcare services (Bose 2014). These geographic obstacles compel migrants to settle within ethnic groups, significantly limiting their potential for long-term integration and assimilation (Wang 2008), with deficient transport constituting a reason for accessibility-related social exclusion (Lucas 2012). Allen et al. (2021) have used spatial filters in regression models to explore the tendency among migrants to settle in specific areas based on their accessibility. The authors consider the influence carpools for commuting have on the choice to settle in specific areas, particularly suburban and rural ones, regardless of the local socio-economic characteristics. The transport system plays a key role as a vector of social relations and a facilitator of integration.

The impact of territorial accessibility on the population (in terms of aging and foreign presence) and the possible existence of local heterogeneities is of particular relevance in this study, especially in relation to the specific geo-demographic characteristics of Italy, which, as described in the introduction of this paper, substantially define its socio-economic and demographic profile.

2.3. On the Spatial Heterogeneity in the Accessibility–Population Change Nexus

In addition to the widely acknowledged benefits that a good transport network has on population growth, numerous empirical studies at a more granular level have reported different findings, due primarily to the geographic heterogeneity of different areas (Chi 2010). The overall effect tends to reflect a collective impact, obviating the local nuances of this general effect, and providing potentially misleading information about local dynamics. The presence of spatial variations in impact is generally attributed to two main factors. First, variations in the effects throughout the various stages of developing the transport infrastructure, with differential impacts during the pre-construction and post-construction phases (Bhatta and Drennan 2003). Second, some studies attribute these variations to the presence of deep spatial and geographic heterogeneities in different areas (Partridge et al. 2008). Given the scope of this study, we focus on the moderating role of the socio-economic characteristics of territories in the accessibility–population change relationship.

Urban, suburban, and rural areas may be significantly different in their growth mechanisms. The literature identifies distinct patterns of depopulation and population loss in urban and local contexts. There is a mutual relationship between rural and urban areas, where the dynamics of one tend to influence the other in an osmotic manner. However, the awareness of differentiated and often non-generalizable results has led numerous scholars to focus exclusively on population change in rural or urban contexts, neglecting the pivotal role of local interaction and contagion dynamics (Wolff and Wiechmann 2018).

Returning to the impact that transport infrastructures have on population change, differentiated effects at the rural/suburban and rural levels have been identified (Chi 2012). In rural areas, transport networks tend to favor population growth. Improving transport networks may attract individuals from more polluted urban areas (Isserman et al. 2009). This improvement may also attract firms, leading to job creation and economic growth (Graham and Gibbons 2019). This, in turn, stimulates local population change (Rasker et al. 2009). Furthermore, by reducing the travel time to surrounding areas, transport networks expose rural areas to larger markets and create more opportunities.

Furthermore, in the international literature on rural depopulation, a central topic is the provision of essential facilities and services necessary for residents in rural areas to maintain an adequate quality of life (Farmer et al. 2012; Neumeier 2016). In this vein, public spatial planning can play a crucial role in addressing issues related to the facility decline (Christiaanse 2020). Following this reasoning, some countries (i.e., The Netherlands) have introduced policies that allocate funds to rural areas to tackle the challenges associated with three key areas, namely housing, economic competitiveness, and the availability of facilities and services (Haartsen and Venhorst 2010).

In suburban areas, improvement in accessibility may have a variety of significant effects. First, better transport networks may increase property values in suburban areas, making them more attractive for residential and commercial uses (Debrezion et al. 2007), positively influencing population growth as people move away from congested urban centers in search of better living conditions (Chi 2012). Second, the progressive strengthening of transport infrastructures contributes to urban expansion, gradually decongesting city centers (Ewing 1997), thus reducing travel time and emissions. Furthermore, it may have certain social and community benefits. Better accessibility in suburban areas may foster social integration by facilitating easier mobility between various locations (Graham and Gibbons 2019). Additionally, it provides suburban residents with better access to essential services, such as healthcare, education, and retail (Litman 2015).

Finally, the relationship between improved accessibility and population change is more complex in urban areas than in surrounding ones. In general, advancements in transportation infrastructure typically follow a U-shaped pattern. Initially, an improved transport network may yield positive effects, fostering connectivity and accessibility to remote neighborhoods and leading to demographic growth. However, beyond a given threshold, additional improvements may have adverse effects, such as environmental pollution, noise, and declining property values near major infrastructures (Chi and Parisi 2011).

Although primarily exploratory in nature, the empirical analysis, which is conducted on a local scale, will allow us to assess how the impact of accessibility on aging and foreign presence may vary across different territorial contexts.

3. Methodology

In this section, the data used to calculate the three indicators in the empirical analysis—RAI, SOP, and SFP—will first be described, along with a brief description of each (Section 3.1). Then, the local spatial autocorrelation analysis is conducted, and the indicator chosen for this purpose will be presented (Section 3.2). Finally, the last part will cover the global (OLS) and local (GWR) regression models used (Section 3.3).

Before proceeding, it seems useful to mention that the analysis was conducted using three distinct software tools, namely GeoDa (version 1.22) and MGWR 2.2 (Oshan et al. 2019) for the spatial econometric analysis and QGIS (version 3.36.2) for the construction of thematic maps.

3.1. Data and Indicators

The data used in this study have been provided by the Italian National Institute of Statistics (ISTAT) and consist of two different datasets. The first one corresponds to the resident population in each Italian municipality in 2021 broken down by age and nationality (i.e., country of citizenship).

The second one is part of a 2021 municipal-level study on accessibility to infrastructure nodes involving four transport networks, namely road, railway, maritime, and air (ISTAT 2023).

The demographic indicators are the share of the older population (SOP), defined as the ratio of people aged 65 and over to the total population per 100 residents, and the share of the foreign population (SFP), defined as the ratio of foreign residents to the total population, also per 100 residents.

In terms of accessibility, we have focused on the motorway and rail transport networks (i.e., land accessibility). ISTAT has recently proposed two distinct accessibility measures for each municipality, namely the distance (in minutes) to the nearest infrastructure, defined as "cost to closest", and the opportunities provided by nearby infrastructures, as determined by the gravitational model. The first measure treats all infrastructures equally in terms of services and options, representing a form of "potential" land accessibility. The second measure considers the actual services and options provided by these infrastructures, influencing an individual's willingness to access them. This latter measure is a more accurate gauge of "real" accessibility to transport infrastructures. In order to have an overall reference for land infrastructure, the indicators published by ISTAT for each municipality for rail and road "real" accessibility were first standardized and then an arithmetic mean was calculated for each municipality. Finally, a min–max approach was used to recalculate this value. This index is defined as the real accessibility index (RAI).

The empirical analysis has been conducted at the municipal level, encompassing slightly more than 7900 statistical units. The geographic data (shape files) for these municipalities have also been provided by ISTAT.

All the data used are available on the official ISTAT website.

3.2. Local Spatial Analysis

The empirical research involves an exploratory spatial data analysis that has been increasingly used in population-based studies in recent years (Matthews and Parker 2013). In the first part of the paper, the spatial distribution of the indicators (RAI, SOP, and SFP) is investigated by using thematic maps and the local univariate G_i^* index of Getis and Ord (Getis and Ord 1992; Ord and Getis 1995).

This index identifies the areas in which comparatively high (or low) values of each indicator are near each other, creating local spatial clusters. Clusters of comparatively high values represent hot spots, which are spatially contiguous areas in which the value of the observed indicator is high. By contrast, clusters of comparatively low values are defined as cold spots and depict contiguous areas in which the value of the observed indicators is low. Finally, there is a third cluster of areas in which no spatial structure is observed, with the distribution following a random pattern.

The attribution of spatial weights involves a first-order queen-based contiguity matrix, whereby two territorial units (i.e., municipalities) are considered adjacent if they share a boundary or geographic limit. The variables in all the spatial autocorrelation analyses are expressed in a standardized form, whereby their means are zero and their variance one. In addition, the spatial weights are standardized in rows. The hypothesis of the existence of a condition of univariate and bivariate spatial clustering has been tested at a 5% level of statistical significance (p-value ≤ 0.05).

3.3. Regression Analysis

The second part of the empirical research involves a regression analysis to understand the net effect of the RAI on SOP and SFP individually. A local regression approach using a geographically weighted regression model (Fotheringham et al. 2003) has, therefore, been adopted using ordinary least square (OLS) models as a benchmark.

The GWR model has been estimated using a golden section algorithm (to identify the best bandwidth, i.e., the number of municipalities for estimating the different local models) and a spatial kernel of the adaptive bi-square type for the process of model-weighting in the calibration phase. This type of kernel is appropriate when the distribution of statistical units (centroid) is not uniform (as in our case; see Figure 1). We have used the corrected Akaike information criterion (AICc) for optimization purposes.

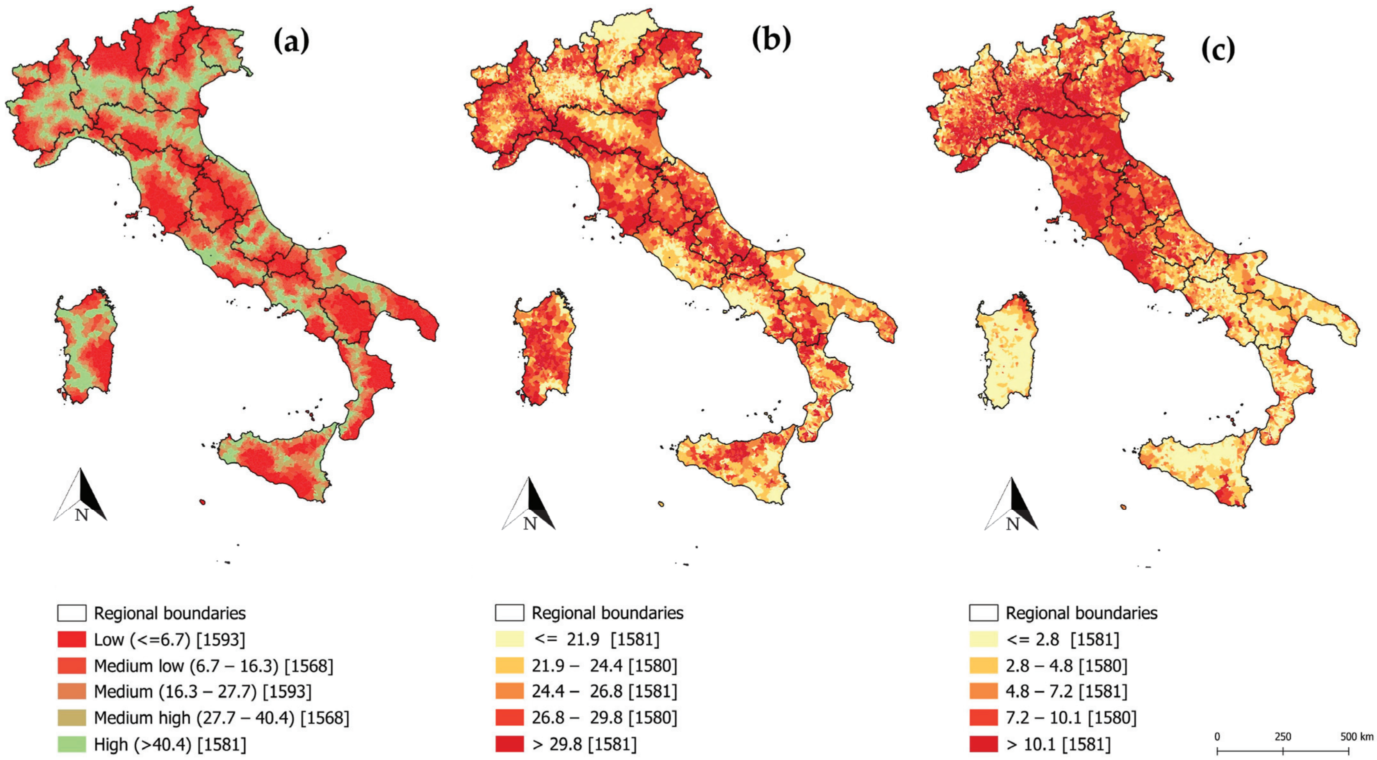

Figure 1. Quantile maps of the RAI (**a**), SOP (**b**), and SFP (**c**). Italian municipalities, 2021.

The regression analysis first estimates an OLS (global and non-spatial) model. This model and its results serve as a benchmark in evaluating the performance of the GWR model. The evaluation of the two models has been conducted according to the standard parameters relating to their explanatory capacity (R^2) and overall performance (AIC). In addition, we evaluated the spatial stationarity in the residuals of both models by conducting a Moran's *I* test for residual spatial autocorrelation (Moran 1948). For this aim, as in the local spatial analysis (Section 3.2), a first-order queen-based contiguity matrix was used.

Prior to the regression analysis, the variables (SOP, SFP, and RAI) have been standardized into a Z distribution, whereby each one of them has a zero mean and a standard deviation of one.

4. Results

This section presents the results of the spatial analysis of the geographic distribution of the selected indicators (Section 4.1), followed by the results of the GWR models, using OLS as a benchmark (Section 4.2)[1].

4.1. Geographic Distribution and Local Spatial Autocorrelation Analysis

The geographic distribution of the three elementary indicators (Figure 1) reveals a complex mosaic in which several spatial patterns can still be discerned. Italy is characterized by a marked heterogeneity in geo-demographic terms, being a foundational characteristic and a distinctive feature (Billari and Tomassini 2021).

Concerning the spatial distribution of the RAI, Figure 1a shows that high values tend to concentrate more near large Italian cities (e.g., Milan, Rome, Naples, Turin, and Florence).

Notably, there is a gradual decline in accessibility levels as one moves away from these urban centers towards progressively more remote ones. This trend is particularly evident when examining the hinterland, which includes municipalities located close to the Apennines and in the foothills of the Alps.

Regarding the spatial distribution of the SOP (Figure 1b), major Italian cities have a less aged population, probably due to the employment opportunities that attract a younger demographic both from other parts of Italy (internal migration) and from abroad (international migration). Figure 1c reveals a clear north–south divide regarding the foreign population. The north accounts for higher values of the RAI, particularly near major cities and areas with an industrial presence. These are Italy's more dynamic areas from a demographic and economic perspective (Buonomo et al. 2024). Although some spatial patterns emerge, such as the urban–rural dichotomy and the north–south divide, the level of heterogeneity remains quite high, due also to the small geographical scale adopted.

Analysis of the local spatial autocorrelation index of Getis and Ord (Figure 2) can help highlight the hot and cold spots in the distributions of the three indicators, thereby making them easier to interpret.

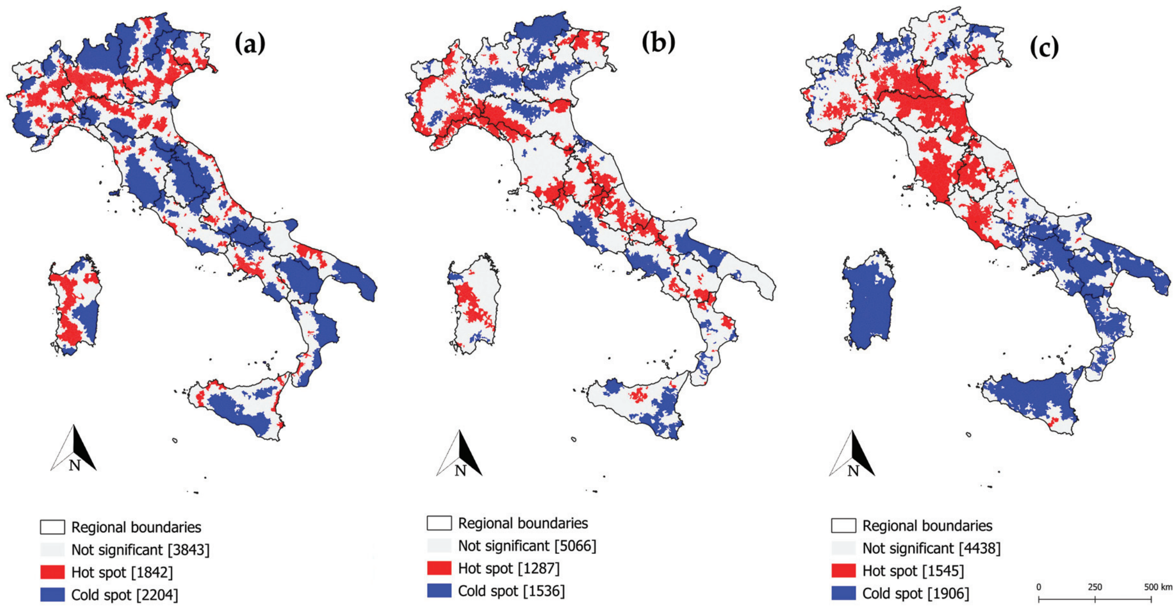

Figure 2. Hot spot and cold spot based on G_i^*. RAI (**a**), SOP (**b**), and SFP (**c**).

The spatial patterns that emerge are quite different from one indicator to another. In the case of the RAI, it is noticeable that inland areas and some coastal ones, particularly located in the southern quadrant and on Sicily and Sardinia, are characterized by clusters of municipalities with low accessibility levels (cold spots). However, this same situation applies to many areas in both northern and central Italy. It is no coincidence that the cold spots outnumber the hot ones (2204 versus 1842). This latter group, however, has a more concentrated geographic distribution in the north, especially in highly urbanized areas. The geographical distribution of Hot Spots in northern Italy, unlike in the south and center, surpasses administrative boundaries, forming supra-regional clusters.

The SOP indicator also shows a higher number of cold spots than hot ones and, compared to RAI its territorial distribution, has fewer clusters (there are 5066 municipalities where the distribution is not spatially dependent). The cold spots mainly affect some areas in the north, including Trentino Alto Adige, a region known for its relatively high birthrate compared to other parts of Italy, as well as much of the Po Valley, and generally the conurbations around large cities, particularly the 14 metropolitan cities (see cartographic Appendix A for a better representation of administrative geographies). Conversely, the hot spots seem to prevail in the hinterland, especially in the center–south. In the north, a vast and compact area of this type of municipal cluster corresponds to parts of Emilia Romagna, the northwestern quadrant, and practically all of Liguria, one of Italy's most aged and demographically fragile regions.

Finally, the SFP indicator is geographically very clear. Italy is essentially split in two. All the hot spots are in the center–north, particularly in urban areas, albeit not exclusively so. Clusters also affect inland and more peripheral areas. The south, and particularly Sicily and Sardinia, contain the bulk of the cold spots.

4.2. Regression Models

The regression analysis should be considered an exploratory approach here, with the aim being to assess the local (and overall) impact of the RAI on the SOP and SFP, without making any causal or explanatory claim.

We have, therefore, estimated two models. SOP is the dependent variable in model 1, and RAI is the independent one. SFP is the dependent variable in model 2, and RAI is, again, the independent one. We first present the results of the overall OLS non-spatial regression model (Table 1), which acts as a benchmark for the local regression model (GWR) at the core of this analysis.

Table 1. OLS model.

Model	Beta	*p*-Value
model 1 (SOP = f RAI)	−0.326	0.000
model 2 (SFP = f RAI)	0.179	0.000
R^2 model 1	0.106	
R^2 model 2	0.032	
AIC model 1	21,542.626	
AIC model 2	22,173.894	
Moran's *I* model 1 residuals	0.578	
Moran's *I* model 2 residuals	0.578	

Overall, there is an inverse relationship between RAI and SOP (−0.326 with a *p*-value of 0.000). This means that accessibility reduces the SOP and, in a certain way, affects the aging process in the different local contexts. As expected, there is a direct relationship between the RAI and SFP (0.179 with *p*-value 0.000). This means that accessibility acts as a magnet for the foreign migrant population, whereby greater accessibility, typically in urban areas (Figure 1, panel a), also increases the SFP. The explanatory capacity of both models is limited, even though the RAI alone in model 1 explains around 11% of the variance in the dependent variable. It is important to remember, nonetheless, that this analysis seeks solely to explore the relationship at the local level between the selected variables.

The GWR models (Table 2) perform better than the OLS models, with a higher R^2 and a lower AIC. However, it is important to note that this better performance is likely largely attributable to the intercept. Moreover, the residual correlation in the GWR models is very close to zero, whereas in the OLS models, the residual correlation is quite high (see Tables 1 and 2).

The local coefficient's summary statistics show that the local parameters (local beta) in both models are characterized by geographic variability.

One of the main strengths of local models is the ability to map local parameters (Matthews and Yang 2012). Figures 3 and 4 show the geographic distribution of the local coefficients. When mapping the local coefficients, we have assumed two t-values to protect against potential false positives resulting from the small bandwidth at which the local regressions are estimated (Yu et al. 2020).

Table 2. GWR model [1].

Model	Mean	Standard Deviation
model 1 (SOP = f RAI)	−0.567	2.840
R^2	0.677	
AIC	15,030.774	
Moran's *I* model 1 residuals	0.036	
model 2 (SFP = f RAI)	0.288	1.629
R^2	0.608	
AIC	16,568.788	
Moran's *I* model 2 residuals	0.036	

[1] Spatial kernel: adaptive bisquare; criterion for optimal bandwidth: AICc; bandwidth used: 45.

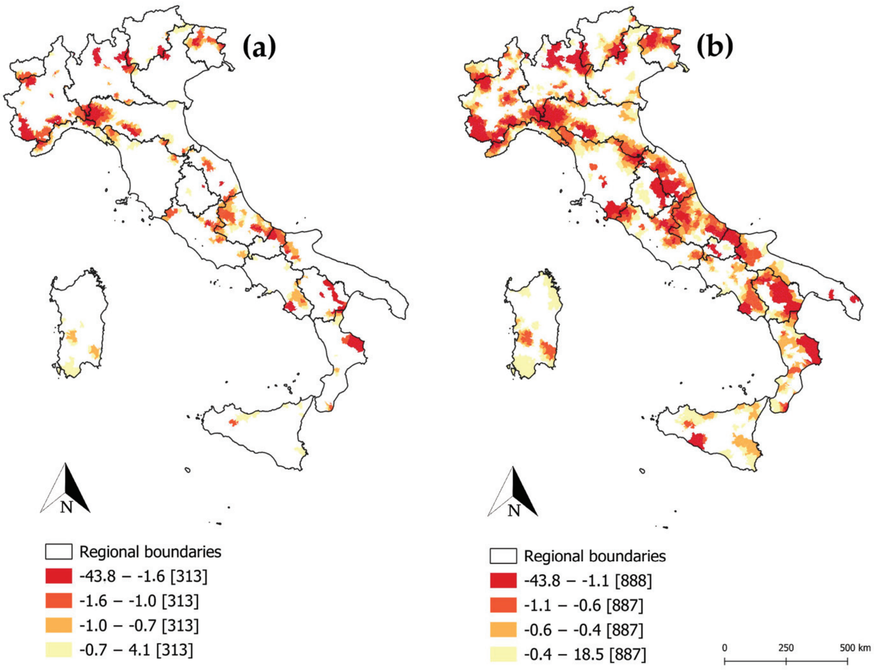

Figure 3. Model 1 (SOP = f RAI). Local beta: (**a**) (t ± 3.83), (**b**) (t ± 1.96).

An analysis of the geographies and intensity of the signs of the local coefficients allows us to identify certain concrete evidence (Figure 3). The most significant negative effects are in the hinterland where, as the indicator's thematic maps show, aging is more intense and greater accessibility significantly reduces it. The effect is mildly negative (and in some cases positive) in coastal areas, where high accessibility increases aging. These are areas with extensive amenities, such as the northwestern part of Sardinia, coastal parts of Sicily, Liguria, and rural areas in Tuscany. These areas have always been affected by retirement migration, including foreign arrivals. In this case, greater accessibility combined with high environmental and territorial capital increases aging. Although generally highly accessible, large cities are not statistically significant. This means that accessibility in urban contexts is not a driver of aging, which is evidently influenced more by other factors.

In the case of the geographies of the local betas of model 2 (Figure 4), the effect is in most of the cases positive, so a higher real accessibility basically corresponds to a higher SFP.

However, what emerges seems interesting and can be summarized as follows.

Accessibility plays a role in the SFP in a heterogeneous way throughout the territory in terms of signs and intensities at the local level. In some cities in the north, the relationship between higher accessibility and a higher SFP is confirmed. In the center and south, this relationship is less apparent. In southern Tuscany, finally, the relationship is negative (or in some cases mildly positive); these are areas where greater accessibility corresponds to a lower SFP (in relative terms). This includes the southern province of Livorno and part of Grosseto, which are not particularly dynamic areas from a demographic point of view, and certainly not especially attractive to foreign arrivals. The same relationship is observed on the southern tip of coastal Lazio and the Ragusa area of eastern Sicily. The situation in the south is fragmented and not easy to interpret, suggesting that there is no link between greater real accessibility and a higher SFP. This is because foreign arrivals in the south prefer locations that are not strictly urban (where lower accessibility is assumed). It should also be considered that the SFP in the south is relatively small (accounting for just under 900,000 in the entire region compared to five million nationwide, of whom 25% are in the center).

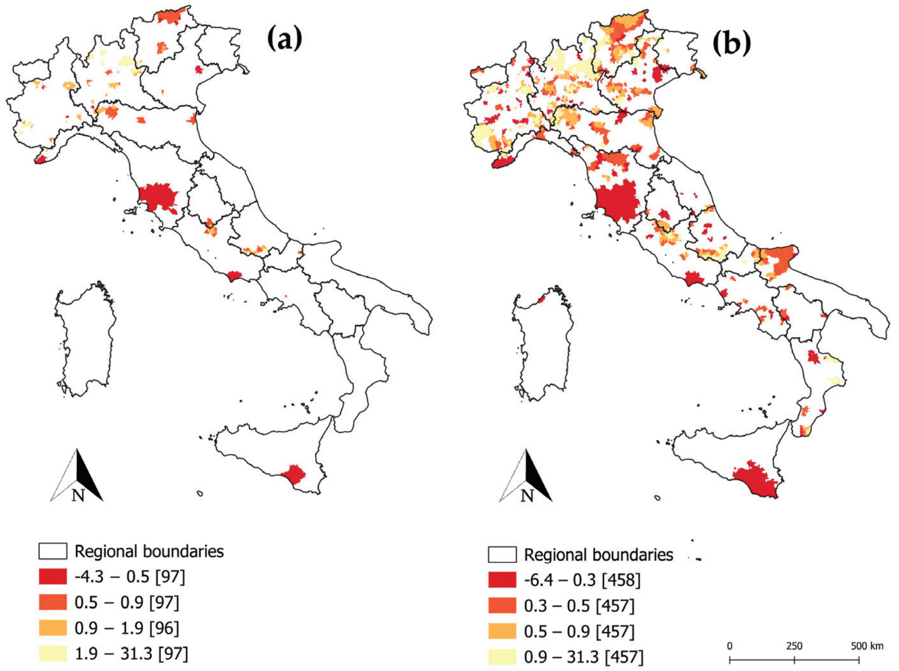

Figure 4. Model 2 (SFP = f RAI). Local beta: (**a**) (t ± 3.83), (**b**) (t ± 1.96).

5. Discussions

Italy is a geographically complex country, characterized by an aging population, persistently low fertility (Billari and Tomassini 2021), and deep territorial divides (Zambon et al. 2020; Viesti 2021). The native population is shrinking, and future demographic forecasts indicate that the population is set to fall sharply, from 59.2 million on 1 January 2021, to 57.9 million in 2030, 54.2 million in 2050, and 47.7 million by 2070.

This decline will not affect the entire territory uniformly, but it is likely to impact those areas that have already been experiencing demographic contraction, if not outright depopulation, for many years (Reynaud et al. 2020).

At the same time, the foreign population is growing, primarily due to the positive net immigration recorded in recent times. This migrant population will significantly impact Italian society and its various territorial contexts in more ways than purely demographics (Termote 2005).

These processes conceal significant local heterogeneity, which although it has already been investigated in various studies, it does not appear, to the best of our knowledge, to have been examined in terms of transport accessibility.

This is quite surprising if we bear in mind that accessibility to territories can play an important role in configuring population settlement patterns by socio-demographic characteristics, such as age or nationality. In this sense, the level of accessibility can make attractive or repulsive a territorial context, influencing its demography. Indeed, demographic dynamics, which can lead to depopulation in some rural areas or to the isolation of subpopulations, such as the elderly one, can depend on the conditions of access to these contexts. The lack of adequate land accessibility often forces rural populations to travel long distances to meet basic needs and access services (Van den Heuvel et al. 2014), and in general, low accessibility is a factor of depopulation and demographic weakness (Panagiotopoulos and Kaliampakos 2024; Melo et al. 2022; Rodríguez-Rodríguez and Larrubia Vargas 2022; Alamá-Sabater et al. 2019, 2021; Sánchez-Mateos and Pulpón 2021), albeit with a certain degree of local variability (Benassi et al. 2021b).

This issue is particularly relevant given the profound differentials in logistical infrastructure (and more) that differentiate the Italian territory—especially at the intra-regional level—and have been addressed by active intervention policies, with the best known and significant being the Strategy for Inner Areas (Barca 2009).

This contribution, which expands upon a preliminary study (Carella et al. 2024), has used local spatial analysis tools to (i) explore the spatial dimension of accessibility (RAI) and two demographic indicators (the share of older population, SOP, and the share of foreign population, SFP) and to (ii) estimate the (global and local) impact of accessibility (RAI) to the other two demographic indicators (SOP and SFP).

The results are naturally partial and improvable, as the study represents an initial, predominantly exploratory, attempt. However, certain emerging elements seem useful for better guiding future studies and for making a few initial considerations.

The first result is that all three indicators are not space independent. On the contrary, their geographical distribution outlines rather clear spatial patterns that only partly reflect the well-known north–south dichotomy. Ignoring this dimension could, therefore, lead to the implementation of ineffective intervention policies. From this perspective, the urgency of thinking locally in terms of quantitative analyses that are useful for territorial planning and local societies becomes quite clear (Fotheringham and Sachdeva 2022)

The accessibility of territories, and, thus, their level of infrastructure and connectivity, has a negative impact on the SOP and a positive one on the SFP. This indicates that better-connected territories are more attractive, less aged, and, one assumes, demographically less static. Greater accessibility is necessary to not only attract people but also to foster territorial redistribution according to a regional demographic development scheme that should aim toward polycentric models (Benassi et al. 2024).

An arrangement of medium-sized cities, well connected to each other, promotes balanced territorial development and defuses processes of spatial polarization in which some areas gain—typically those with high accessibility—while others that are geographically isolated and aged lose out (Cardoso 2022).

In the long run, demographic and territorial systems of this nature, based on competitive rather than cooperative/redistributive logics, are destined to lose out overall, concerning both urban populations—compressed into spaces defined by low quality of life and significant environmental impacts—and those living in rural or non-urban contexts that seem destined to disappear, except for rare cases, where the lack of essential services and dynamic labor markets leads to significant demographic contraction and depopulation (Benassi et al. 2021b).

Even within a framework of high local heterogeneity, investing in accessibility seems capable of "breaking" this polarized dynamic, reconnecting places, and, thus, promoting the connection of populations. Naturally, it is necessary to consider smart and environmentally friendly forms of mobility.

It is, therefore, crucial to develop policies that both maximize the area's connectivity by enhancing infrastructure and improving physical accessibility, also taking into account increasing the attractiveness by strengthening its economic competitiveness.

In this direction, a combination of national/regional and local policy interventions should be implemented. These could include the improvement of public transportation networks, subsidized public transportation programs, or rural connectivity initiatives able to improve accessibility in rural or less populated areas. In terms of enhancing the competitiveness of these areas, public policy initiatives could include measures such as income tax reductions, offering housing at symbolic prices to individuals who choose to settle permanently in rural areas or regions experiencing progressive population aging (as already implemented in at-risk areas of Sicily), or implementing labor market incentive policies at the macro-regional level (i.e., promoting female or youth entrepreneurship).

The combination of these strategies (at the macro and micro-local level) could make these areas more appealing to migrants from other parts of Italy and abroad, thereby potentially mitigating the effects of population aging (Benassi et al. 2024)

The findings of this study can act as a valuable guide, emphasizing the significance of adopting a local approach to planning public efforts. Additionally, the study highlights the importance of considering territory accessibility (alongside economic and social factors) when formulating both macro and micro policy actions.

However, it is important to recognize that a local approach may lead to results that are not generalizable across different local areas, but it is specific to the reference area. If this method can be time-consuming and costly, applying a macro global model risks leading to misleading results. The social cohesion of the various local contexts, as has always been emphasized even at the European level (European Commission 1999), depends on connected and interacting territorial systems capable of attracting population (domestically but also and especially from abroad) and promoting territorial redistribution. Investing in accessibility may well marshal this necessary change, even if only partially so.

6. Conclusions

The aging of the population and foreign presence (due to international migration) are two of the most important demographic processes currently ongoing in Italy (Billari and Tomassini 2021). Usually, the foreign population has been seen as a counteractor of the aging of the population due to its younger age structure and comparatively higher level of fertility, at least in the short and midterm. The paper showed that both processes (aging and foreign presence) are essentially spatial processes characterized by spatial variability and spatial dependence. Moreover, results showed that accessibility can play a pivotal role in such demographic processes, although in a framework of a high level of local heterogeneity. Based on the regression results, we can say that policies aimed at improving the level of accessibility of the local territorial contexts could have positive impacts on local demographic imbalances.

Nevertheless, in line with the results of other contributions (Iammarino et al. 2019; Panagiotopoulos and Kaliampakos 2024), although improving accessibility plays a key role in shaping the territorial distribution and (re)distribution of people and economic activities, spatial inequalities can only be addressed through appropriate locally tailored policies. From this perspective, local approaches confirm their usefulness in supporting place-based policies (Fotheringham and Sachdeva 2022; Benassi et al. 2024).

The study has some limitations and leaves some open doors for further development. In terms of limitations, it should be noted that the analysis is based on three indicators related to a single year and computed based on cross-section data. The analysis conducted is explorative, and the regression models used (OLS and GWR) are very simple in terms of covariates.

Further developments could regard the implementation of a diachronic analysis so that we can refer to the level of accessibility to some measures of population change (such as demographic growth rate or similar). We could enrich the mode-independent variables and, therefore, try to use a local regression model with a varying bandwidth, namely the multiscale geographically weighted regression model (MGWR).

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Appendix A

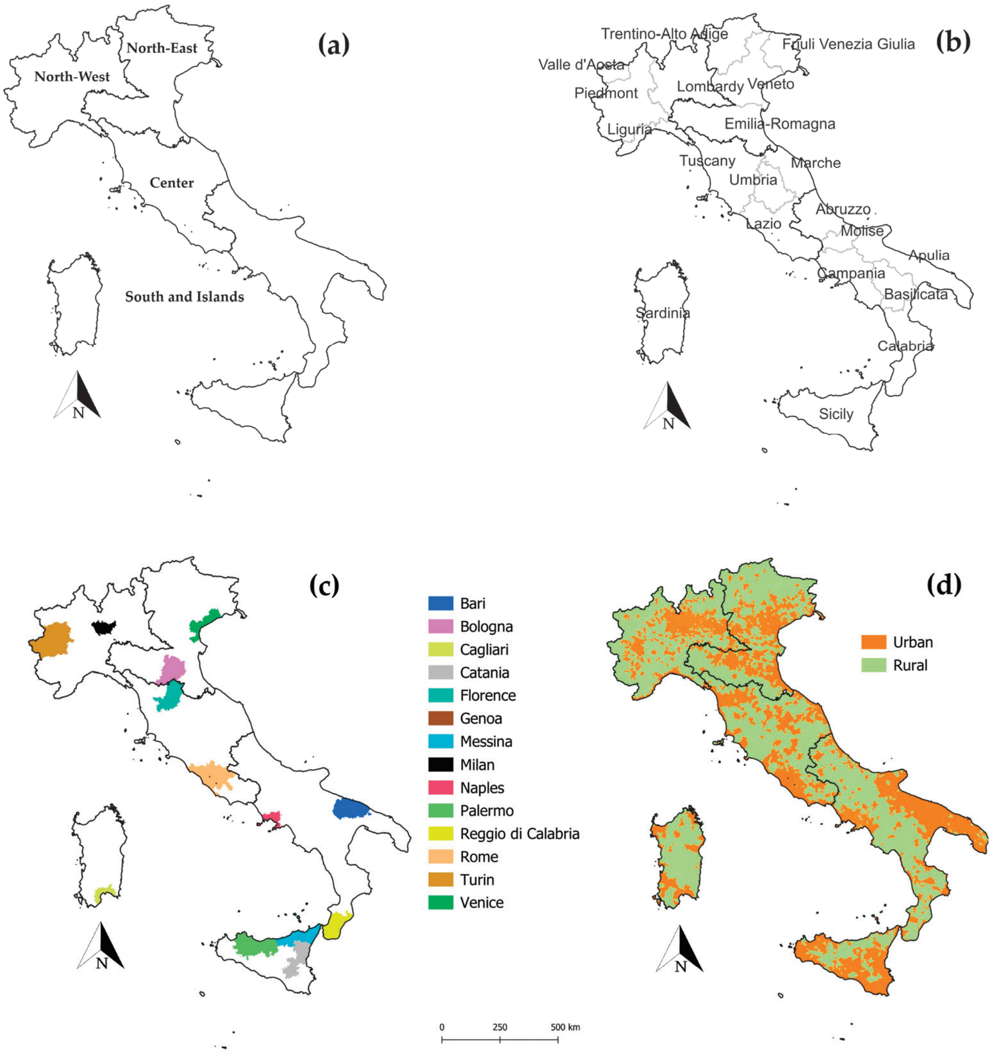

Figure A1. Italian geographies. (**a**) Macro regions; (**b**) Regions; (**c**) Metropolitan cities; (**d**) Urban (Cities, Towns and Suburbs) and Rural Municipalities.

Notes

[1] For a better reading and interpretation of the results, it is recommended to consult not only the maps included in this section but also those provided in the Appendix of the contribution, which relate respectively to the Italian macro-regions, Italian regions, Italian metropolitan cities, and Italian municipalities classified as urban and rural according to the degree of urbanization (Degurba) indicator.

References

Alamá-Sabater, Luisa, Vincente Budí, Josè Maria G. Álvarez-Coque, and Norat Roig-Tierno. 2019. Using mixed research approaches to understand rural depopulation. *Economía Agraria y Recursos Naturales-Agricultural and Resource Economics* 19: 99–120.

Alamá-Sabater, Luisa, Vincente Budí, Norat Roig-Tierno, and Josè Maria G. Álvarez-Coque. 2021. Drivers of depopulation and spatial interdependence in a regional context. *Cities* 114: 103217. [CrossRef]

Allen, Jeff, Steven Farber, Stephen Greaves, Geoffrey Clifton, Hao Wu, Somwrita Sarkar, and David M. Levinson. 2021. Immigrant settlement patterns, transit accessibility, and transit use. *Journal of Transport Geography* 96: 103187. [CrossRef]

Annunziata, Alfonso, Francesco Scorza, Simone Corrado, and Beniamino Murgante. 2024. Unveiling intra-rural divides: Investigating decline and prosperity in rural areas. The case study of southern Italy. *European Planning Studies* 32: 1478–505. [CrossRef]

Armenise, Massimo, Federico Benassi, Marica D'Elia, Marianna Mantuano, and Francesca Petrei. 2022. The Exposure Geography of Italian Local Economies to Major Foreign Ones. Evidence from a Multiscale Spatial Experiment Based on Granularity. *Jahrbücher für Nationalökonomie und Statistik—Journal of Economics and Statistics* 242: 87–105. [CrossRef]

Bagavos, Christos. 2022. On the contribution of foreign-born populations to overall population change in Europe. *Demographic Research* 46: 179–216. [CrossRef]

Barca, Fabrizio. 2009. *An Agenda for a Reformed Cohesion Policy. A Place-Based Approach to Meeting EU Challenges and Expectations*. Brussels: European Commission, pp. 1–248.

Barca, Fabrizio. 2019. Place-based policy and politics. *Renewal: A Journal of Social Democracy* 27: 84–95.

Benassi, Federico, Annalisa Busetta, Gerardo Gallo, and Manuela Stranges. 2021a. Diseguaglianze tra territori. In *L'Italia e le Sfide della Demografia*. Edited by Francesco C. Billari and Cecilia Tomassini. Bologna: Il Mulino, Rapporto Sulla Popolazione, pp. 135–62.

Benassi, Federico, Annalisa Busetta, Gerardo Gallo, and Manuela Stranges. 2023. Neighbourhood effects and determinants of population changes in Italy: A spatial perspective. *Vienna Yearbook of Population Research* 23: 311–38. [CrossRef]

Benassi, Federico, Cecilia Tomassini, and Carlo Lallo. 2024. The local regression approach as a tool to improve place-based policies: The case of Molise (Southern Italy). *Spatial Demography* 12: 1–28. [CrossRef]

Benassi, Federico, Marica D'Elia, and Francesca Petrei. 2021b. The "meso" dimension of territorial capital: Evidence from Italy. *Regional Science Policy and Practice* 13: 159–75. [CrossRef]

Berechman, Joseph, and Robert Paaswell. 2001. Accessibility improvements and local employment: An empirical analysis. *Journal of Transportation and Statistics* 4: 49–66.

Bhatta, Saurav Dev, and Matthew P. Drennan. 2003. The economic benefits of public investment in transportation: A review of recent literature. *Journal of Planning Education and Research* 22: 288–96. [CrossRef]

Billari, Francesco C., and Cecilia Tomassini. 2021. *Rapporto sulla Popolazione. L'Italia e le Sfide della Demografia*. Bologna: Il Mulino, pp. 1–262.

Bose, Pablo S. 2014. Refugees in Vermont: Mobility and acculturation in a new immigrant destination. *Journal of Transport Geography* 36: 151–59. [CrossRef]

Buonomo, Alessio, Federico Benassi, Gerardo Gallo, Luca Salvati, and Salvatore Strozza. 2024. In-between centers and suburbs? Increasing differentials in recent demographic dynamics of Italian metropolitan cities. *Genus* 80: 1. [CrossRef]

Burnley, Ian H. 2002. Evolution of Chinese settlement geographies in Sydney, Australia. *Urban Geography* 23: 365–87. [CrossRef]

Campagnucci, Fabiano, and Gabriele Morettini. 2024. Inner areas matter: A place-sensitive approach for the identification of the daily life spaces in the Italian Abruzzo region. *Socio Economic Planning Sciences* 93: 101859. [CrossRef]

Cardille, Jeffrey A., Stephen J Ventura, and Monica G. Turner. 2001. Environmental and social factors influencing wildfires in the Upper Midwest, United States. *Ecological Applications* 11: 111–27. [CrossRef]

Cardoso, Rodrigo Viseu. 2022. City-regional demographic composition and the fortunes of regional second cities. *Urban Geography* 44: 1541–63. [CrossRef]

Carella, Maria, Federico Benassi, Roberta Misuraca, and Massimo Armenise. 2024. Accessibility, population ageing, and foreign presence: A first investigation across local heterogeneities in Italy. In *La Geografía ante los Retos del Desarrollo Local*. Edited by Francisco Javier García-Delgado, María Hernández-Hernández, Antonio Martínez-Puche, Luis Alfonso Hortelano Mínguez and Vicente M. Zapata Hernández. XII Coloquio de Desarrollo Local—I European Meeting on Geography and Local Development. Alicante: University of Alicante, pp. 186–92. [CrossRef]

Caschili, Simone, Andrea De Montis, and Daniele Trogu. 2015. Accessibility and rurality indicators for regional development. *Computers, Environment and Urban Systems* 49: 98–114. [CrossRef]

Chi, Guangqing. 2010. The impacts of highway expansion on population change: An integrated spatial approach. *Rural Sociology* 75: 58–89. [CrossRef]

Chi, Guangqing. 2012. The impacts of transport accessibility on population change across rural, suburban and urban areas: A case study of Wisconsin at sub-county levels. *Urban Studies* 49: 2711–31. [CrossRef]
Chi, Guangqing, and David W. Marcouiller. 2009. Rethinking the Migration Effects of Natural Amenities: Part II. *Canadian Journal of Regional Science* 32: 349–59.
Chi, Guangqing, and Domenico Parisi. 2011. Highway expansion effects on urban racial redistribution in the post—Civil rights period. *Public Works Management and Policy* 16: 40–58.
Chiocchini, Raffaela, and Sandro Cruciani. 2009. L'accessibilità ai nodi infrastrutturali: Un'applicazione sperimentale attraverso l'uso di strumenti GIS. In *Indicatori e Modelli Statistici per la Valutazione degli Squilibri Territoriali*. Edited by Giorgio Alleva and Piero Demetrio Falorsi. Milano: Franco Angeli, pp. 309–42.
Christiaanse, Suzan. 2020. Rural facility decline: A longitudinal accessibility analysis questioning the focus of Dutch depopulation-policy. *Applied Geography* 121: 102251. [CrossRef]
Costa da Silva Firmino, Diego, J. Paul Elhorst, and Raul da Mota Silveira Neto. 2017. Urban and rural population growth in a spatial panel of municipalities. *Regional Studies* 51: 894–908. [CrossRef]
Dalvi, M. Quasim, and Keith M. Martin. 1976. The measurement of accessibility: Some preliminary results. *Transportation* 5: 17–42. [CrossRef]
Darwent, David F. 1969. Growth poles and growth centers in regional planning—A review. *Environment and Planning A* 1: 5–31. [CrossRef]
De Montis, Andrea, and Aura Reggiani. 2012. JTG special section on accessibility and socio-economic activities: Methodological and empirical aspects. *Journal of Transport Geography* 25: 95–97. [CrossRef]
Debrezion, Ghebreegziabiher, Eric Pels, and Piet Rietveld. 2007. The impact of railway stations on residential and commercial property value: A meta-analysis. *The Journal of Real Estate Finance and Economics* 35: 161–80. [CrossRef]
Delfmann, Heike. 2014. Why start a business in a declining rural area with an ageing society? A UK–NL case study. Presented at the 54th Congress of the European Regional Science Association: "Regional Development and Globalisation: Best Practices", St. Petersburg, Russia, August 26–29.
Ehrenhalt, Alan. 2012. The Public Service Heritage. In *Human Resource Management in Public Service: Paradoxes, Processes, and Problems*. Thousand Oaks: SAGE Publications, p. 11.
European Commission. 1999. *European Spatial Development Perspective: Towards Balanced and Sustainable Development of the Territory of EU*. Luxembourg: Publications Office for the European Union.
Ewing, Reid. 1997. Is Los Angeles-style sprawl desirable? *Journal of the American Planning Association* 63: 107–26. [CrossRef]
Farmer, Jane, Amy Nimegeer, John H. Farrington, and Gaener Rodger. 2012. Rural citizens' rights to accessible health services: An exploration. *Sociologia Ruralis* 52: 134–44. [CrossRef]
Farrell, Chad R. 2016. Immigrant suburbanisation and the shifting geographic structure of metropolitan segregation in the United States. *Urban Studies* 53: 57–76. [CrossRef]
Fotheringham, A. Stewart, and Mehak Sachdeva. 2022. On the importance of thinking locally for statistics and society. *Spatial Statistics* 50: 100601. [CrossRef]
Fotheringham, A. Stewart, Chris Brunsdon, and Martin Charlton. 2003. *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*. Hoboken: Wiley & Sons.
Gesano, Giuseppe, and Salvatore Strozza. 2011. Foreign migrations and population aging in Italy. *Genus* 67: 83–104.
Getis, Arthur, and Keith J. Ord. 1992. The analysis of spatial association by use of distance statistics. *Geographical Analysis* 24: 189–206. [CrossRef]
Geurs, Karst T., and Bert van Wee. 2004. Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography* 12: 127–40. [CrossRef]
Geurs, Karst T., and Jan R. Ritsema van Eck. 2001. *Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-Use Transportation Scenarios, and Related Social and Economic Impact*. RIVM Rapport 408505006. Bilthoven: National Institute for Public Health and the Environment.
Glaeser, Edward L., Jose A. Scheinkman, and Andrei Shleifer. 1995. Economic growth in a cross-section of cities. *Journal of Monetary Economics* 36: 117–43. [CrossRef]
Golini, Antonio, Antonio Mussino, and Mira Savioli. 2000. *Il Malessere Demografico in Italia. Una Ricerca sui Comuni Italiani*. Bologna: Il Mulino.
Graham, Daniel J., and Stephen Gibbons. 2019. Quantifying wider economic impacts of agglomeration for transport appraisal: Existing evidence and future directions. *Economics of Transportation* 19: 100121. [CrossRef]
Graves, Philip E. 1983. Migration with a composite amenity: The role of rents. *Journal of Regional Science* 23: 541–46. [CrossRef]
Gutiérrez, Javier, Ana Condeço-Melhorado, and Juan Carlos Martín. 2010. Using accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment. *Journal of Transport Geography* 18: 141–52. [CrossRef]
Haartsen, Tialda, and Viktor Venhorst. 2010. Planning for decline: Anticipating on population decline in the Netherlands. *Tijdschrift Voor Economische en Sociale Geografie* 101: 218–27. [CrossRef]
Handy, Susan L., and Debbie A. Niemeier. 1997. Measuring accessibility: An exploration of issues and alternatives. *Environment and planning A* 29: 1175–94. [CrossRef]
Hansen, Walter G. 1959. How accessibility shapes land use. *Journal of the American Institute of Planners* 25: 73–76. [CrossRef]

Harper, Sarah. 2014. Economic and social implications of aging societies. *Science* 346: 587–91. [CrossRef]
Hiebert, Daniel. 2000. Immigration and the changing Canadian city. *Canadian Geographer/Le Géographe Canadien* 44: 25–43. [CrossRef]
Iammarino, Simona, Andrés Rodriguez-Pose, and Michael Storper. 2019. Regional inequality in Europe: Evidence, theory and policy implications. *Journal of Economic Geography* 19: 273–98. [CrossRef]
Isserman, Andrew M., Edward Feser, and Drake E. Warren. 2009. Why some rural places prosper and others do not. *International Regional Science Review* 32: 300–42. [CrossRef]
ISTAT. 2023. *L'Accessibilità dei Comuni alle Principali Infrastrutture di Trasporto*. Rome: Statistiche Focus.
Karou, Saleem, and Angela Hull. 2014. Accessibility modelling: Predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK. *Journal of Transport Geography* 35: 1–11. [CrossRef]
Kazemipur, Abdolmohammad, and Shiva Halli. 2000. The invisible barrier: Neighbourhood poverty and integration of immigrants in Canada. *Journal of International Migration and Integration/Revue de l'Integration et de la Migration Internationale* 1: 85–100. [CrossRef]
Kneebone, Elizabeth, and Emily Garr. 2010. *The Suburbanization of Poverty*. Washington, DC: Brookings Institute.
La Bianca, Marilena, and Francisco Navarro Valverde. 2019. Depopulation and aging in rural areas in the European Union: Practicing starting from the LEADER approach. *Perspectives on Rural Development* 3: 223–52.
Litman, Todd. 2015. *Evaluating Public Transit Benefits and Costs*. Victoria: Victoria Transport Policy Institute.
Lo, Lucia, Amir Shalaby, and Baha Alshalalfah. 2011. Relationship between immigrant settlement patterns and transit use in the Greater Toronto Area. *Journal of Urban Planning and Development* 137: 470–76. [CrossRef]
Lucas, Karen. 2012. Transport and social exclusion: Where are we now? *Transport Policy* 20: 105–13. [CrossRef]
Lundberg, Johan. 2006. Spatial interaction model of spillovers from locally provided public services. *Regional Studies* 40: 631–44. [CrossRef]
Matthews, Stephen A., and Daniel M. Parker. 2013. Progress in spatial demography. *Demographic Research* 28: 271–312. [CrossRef]
Matthews, Stephen A., and Tse-Chuan Yang. 2012. Mapping the results of local statistics: Using geographically weighted regression. *Demographic Research* 26: 151–66. [CrossRef]
Melo, Patricia C., Conceiccao Rego, Paulo R. Anciães, Nuno Guiomar, and Josè Muñoz-Rojas. 2022. Does road accessibility to cities support rural population growth? Evidence for Portugal between 1991 and 2011. *Journal of Regional Science* 62: 443–70. [CrossRef]
Moran, Patrick A.P. 1948. The interpretation of statistical maps. *Journal of the Royal Statistical Society B* 10: 243–51. [CrossRef]
Moya-Gómez, Borja, Maria Henar Salas-Olmedo, Juan Carlos García-Palomares, and Javier Gutiérrez. 2018. Dynamic accessibility using big data: The role of the changing conditions of network congestion and destination attractiveness. *Networks and Spatial Economics* 18: 273–90. [CrossRef]
Muti, Ördecan. 2023. Regional Population Diversity and Social Cohesion in the Local Context. Population Policy Discussion Paper, 20. Available online: https://population-europe.eu/files/documents/dp_reg_pop_div_web_18.07.pdf (accessed on 5 September 2024).
Neumeier, Stefan. 2016. Accessibility to services in rural areas. *disP–The Planning Review* 52: 32–49. [CrossRef]
OECD, The European Commission, Food and Agriculture Organization of the United Nations, United Nations Human Settlements Programme, International Labour Organization, and The World Bank. 2021. Applying the Degree of Urbanisation: A Methodological Manual to Define Cities, Towns and Rural Areas for International Comparisons. In *OECD Regional Development Studies*. Paris: OECD Publishing. Brussels: European Union. [CrossRef]
Ord, Keith J., and Arthur Getis. 1995. Local spatial autocorrelation statistics: Distributional issues and an application. *Geographical Analysis* 24: 286–306. [CrossRef]
Oshan, Taylor M., Ziqi Li, Wei Kang, Levi J. Wolf, and A. Stewart Fotheringham. 2019. Mgwr: A Python implementation of multiscale geographically weighted regression for investigating process spatial heterogeneity and scale. *ISPRS International Journal of Geo-Information* 8: 269. [CrossRef]
Ozbay, Kaan, Dilruba Ozmen, and Joseph Berechman. 2006. Modeling and analysis of the link between accessibility and employment growth. *Journal of Transportation Engineering* 132: 385–93. [CrossRef]
Panagiotopoulos, George, and Dimitris Kaliampakos. 2024. Accessibility, rural depopulation & the Modified Areal Unit Problem: An analysis of mainland Greece. *European Journal of Geography* 15: 42–53.
Partridge, Mark D., Dan S. Rickman, Kamar Ali, and M. Rose Olfert. 2008. The geographic diversity of US nonmetropolitan growth dynamics: A geographically weighted regression approach. *Land Economics* 84: 241–66. [CrossRef]
Patuelli, Roberto, Aura Reggiani, Sean P. Gorman, Peter Nijkamp, and Franz-Josef Bade. 2007. Network analysis of commuting flows: A comparative static approach to German data. *Networks and Spatial Economics* 7: 315–31. [CrossRef]
Rasker, Ray, Patricia H. Gude, Justin A. Gude, and Jeff Van den Noort. 2009. The economic importance of air travel in high-amenity rural areas. *Journal of Rural Studies* 25: 343–53. [CrossRef]
Rees, Philip, Nicole van der Gaag, Joop de Beer, and Frank Heins. 2012. European regional populations: Current trends, future pathways and policy options. *European Journal of Population* 28: 385–416. [CrossRef]
Reitz, Jeffrey G. 2002. Host societies and the reception of immigrants: Research themes, emerging theories and methodological issues. *International Migration Review* 36: 1005–19. [CrossRef]
Reynaud, Cecilia, and Sara Miccoli. 2023. Demographic sustainability in Italian territories: The link between depopulation and population ageing. *Vienna Yearbook of Population Research* 21: 1–22. [CrossRef]

Reynaud, Cecilia, Sara Miccoli, Federico Benassi, Alessia Naccarato, and Luca Salvati. 2020. Unravelling a demographic 'Mosaic': Spatial patterns and contextual factors of depopulation in Italian Municipalities, 1981–2011. *Ecological Indicators* 115: 106356. [CrossRef]

Roback, Jennifer. 1982. Wages, rents, and the quality of life. *Journal of political Economy* 90: 1257–78. [CrossRef]

Rodríguez-Rodríguez, David, and Remedios Larrubia Vargas. 2022. Protected areas and rural depopulation in Spain: A multi-stakeholder perceptual study. *Land* 11: 384. [CrossRef]

Rosina, Alessandro, and Roberto Impicciatore. 2022. *Storia Demografia d'Italia. Crescita, Crisi e Sfide*. Rome: Carocci, pp. 1–187.

Salvati, Luca. 2014. Population distribution and urban growth in Southern Italy, 1871–2011: Emergent polycentrism or path-dependent monocentricity? *Urban Geography* 35: 440–53. [CrossRef]

Sánchez-Mateos, Martínez, and Ruiz A. R. Pulpón. 2021. Closeness is not accessibility: Isolation and depopulated rural areas in the proximity of metropolitan urban areas, a case-study in inland Spain. *European Countryside* 13: 410–35. [CrossRef]

Shelukdov, Alexander, Johannes Kamp, and Daniel Müller. 2020. Decreasing labor intensity in agriculture and the accessibility of major cities shape the rural population decline in postsocialist Russia. *Eurasian Geography and Economics* 62: 481–506.

Solé-Ribalta, Albert, Sergio Gómez, and Alex Arenas. 2018. Decongestion of urban areas with hotspot pricing. *Networks and Spatial Economics* 18: 33–50. [CrossRef]

Staniscia, Barbara, and Federico Benassi. 2018. Does regional development explain international youth mobility? Spatial patterns and global/local determinants of the recent emigration of young Italians. *Belgeo. Reveu Belge de Géographie* 3: 1–25.

Stepniak, Marcin, and Piotr Rosik. 2018. The role of transport and population components in change in accessibility: The influence of the distance decay parameter. *Networks and Spatial Economics* 18: 291–312. [CrossRef]

Strozza, Salvatore, Federico Benassi, Raffaele Ferrara, and Gerardo Gallo. 2016. Recent demographic trends in the major Italian urban agglomerations: The role of foreigners. *Spatial Demography* 4: 39–70. [CrossRef]

Termote, Marc. 2005. Implicazioni urbane dei mutamenti demografici e economici nei paesi sviluppati. Il caso Italiano. *Rivista Italiana di Economia, Demografia e Statistica* 54: 75–85.

Thompson, Chris, and Tim Bawden. 1992. What are the potential economic development impacts of high-speed rail? *Economic Development Quarterly* 6: 297–319. [CrossRef]

Tragaki, Alexandra, and Antonis Rovolis. 2014. Immigrant population in Italy during the first decade of the 21st century: Changing demographics and modified settlement patterns. *European Urban and Regional Studies* 21: 286–300. [CrossRef]

Van den Heuvel, Frank P., Liliana Rivera, Karel H. Van Donselaar, Ad de Jong, Yossi Sheffi, Peter W. de Langen, and Jan C. Fransoo. 2014. Relationship between freight accessibility and logistics employment in US counties. *Transportation Research Part A: Policy and Practice* 59: 91–105. [CrossRef]

Vickerman, Roger. 1974. Accessibility, attraction, and potential: A review of some concepts and their use in determining mobility. *Environment and Planning A* 6: 675–91. [CrossRef]

Vickerman, Roger, Klaus Spiekermann, and Michael Wegener. 1999. Accessibility and economic development in Europe. *Regional Studies* 33: 1–15. [CrossRef]

Viesti, Gianfranco. 2021. *Centri e Periferie: Europa, Italia, Mezzogiorno dal XX al XXI Secolo*. Bari: Giuseppe Laterza e Figli.

Voss, Paul R., and Guangqing Chi. 2006. Highways and population change. *Rural Sociology* 71: 33–58. [CrossRef]

Wang, Qingfang. 2008. Race/ethnicity, gender and job earnings across metropolitan areas in the United States: A multilevel analysis. *Urban Studies* 45: 825–43. [CrossRef]

Wolff, Manuel, and Thorsten Wiechmann. 2018. Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990–2010. *European Urban and Regional Studies* 25: 122–39. [CrossRef]

Yu, Hanchen, A. Stewart Fotheringham, Ziqi Li, Taylor Oshan, Wei Kang, and Levi John Wolf. 2020. Inference in multiscale geographically weighted regression. *Geographical Analysis* 52: 87–106. [CrossRef]

Zambon, Ilaria, Kostas Rontos, Cecilia Reynaud, and Luca Salvati. 2020. Toward an unwanted divided? Fertility decline and the North-South divide in Italy, 1952–2018. *Quality and Quantity* 54: 169–87. [CrossRef]

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Article

Shifting Sands: Examining and Mapping the Population Structure of Greece Through the Last Three Censuses

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Abstract: This paper aims to facilitate a more nuanced understanding of regional disparities in the population age structure at a local scale by applying a recent method for visualizing these disparities. Utilizing data from the three most recent population censuses in Greece, this method applies advanced data visualization techniques to map age distributions, highlighting significant variations in aging patterns across municipalities, towns, and districts. Traditional demographic analysis often overlooks local heterogeneities, leading to broad policies that often fail to address the unique needs of specific regions. Detailed maps are created by integrating geographic data with census data (using R and GIS), enabling policymakers to pinpoint areas with specific demographic challenges and opportunities. This localized approach reveals critical insights, such as regions experiencing rapid population aging, areas with younger population profiles, and zones undergoing demographic transitions. The visualization tool significantly improves the formulation of targeted strategies, enhancing the effectiveness of policies related to healthcare, workforce planning, and social services distribution. Through case studies and comparative analysis, we demonstrate the practical applications and advantages of this method in shaping public policy and strategic planning. This paper contributes to the field of geodemography by introducing and demonstrating a visualization method that enhances the accuracy of demographic analysis, providing policy makers with useful information to better address local demographic challenges and tailor strategies to specific regional needs.

Keywords: population; age structure; aging; census; mapping; regional variations; inequalities; geodemography; GIS

1. Introduction

A country's population census serves as the primary source of information regarding the population's size, geographic distribution, and social, demographic, and economic characteristics (UNFPA 2002; Baffour et al. 2013; Killick et al. 2016; MacDonald 2019). The census aims to produce statistics that are relevant and useful to the end users—citizens and organizations (Warren 2014). This is its main statistical objective (Ricciato et al. 2020). Therefore, every action related to the census should focus on delivering a product that meets the needs of these users, whether they are individuals or organizations interested in the data. The data collected through the census offer insights into various aspects of society, enabling the implementation of appropriate policy interventions. By ensuring that census data are effectively utilized and communicated, the development of targeted policies and strategies that better address the diverse needs of society is enhanced.

The organization responsible for conducting the census meticulously plans and designs all of the necessary tools and measures to ensure that the task is successfully executed. Given that the data are ultimately intended for user consumption, many of the questions included in the census may be formulated in consultation with these users. Conducting a census is an expensive undertaking, funded by the users themselves, which necessitates careful and thoughtful design (United Nations 2001).

Censuses are primarily conducted to gather crucial information that governments need to develop appropriate policies, improve public services, and support research by providing accessible data. These data serve as the foundation for understanding demographic trends and making informed decisions at both local and national levels. They can be used to produce statistics on the population and its characteristics, offering a snapshot of the population in a specific area at a specific point in time, complete with spatial references. Traditional censuses, involving the direct enumeration of the entire population, remain widely used and provide invaluable resources for comprehensive and detailed studies of a country's demographic profile (Yildiz and Smith 2015).

What sets the census apart from other statistical data sources is its comprehensive geographical coverage. This wide-reaching scope allows for a detailed and representative analysis of demographic patterns across diverse areas. It encompasses the entire country, ensuring that every region is included. Another key advantage is the comparability of statistics across different census periods, allowing for consistent and reliable data on all individuals residing in any specific area or subgroup within the population (UNFPA 2002).

Demography is the study of populations (Landry 1945). Population structure is a fundamental indicator of a country's demographic profile, reflecting trends in birth rates (Tragaki and Lasaridi 2009), mortality rates (Andreopoulos et al. 2021, 2023a, 2023b), and migration (Rovolis and Tragaki 2006; Vollset et al. 2020). Grasping the dynamics of the population structure at both the national and local levels is crucial for policy makers, researchers, and communities, as it offers insights into societal challenges and opportunities (Matthews and Parker 2013). Over the past two decades, Greece has experienced substantial demographic changes, driven by factors such as a rising life expectancy, declining fertility rates, and changing migration patterns. Understanding these demographic shifts at a local level is essential for capturing the nuances of population changes across regions. Mapping and analyzing the population structure in Greece during that period offers critical insights into the country's demographic evolution and can inform the development of strategies to address emerging challenges. Population aging has emerged as a prominent demographic trend in Greece, mirroring the global patterns observed in many developed countries. As life expectancy rises and birth rates continue to decline, the proportion of older persons within the population is steadily growing (Kotzamanis 2009; Kotzamanis et al. 2018). This demographic shift has significant implications for various aspects of Greek society, including healthcare systems, labor markets, and social welfare programs. Regional disparities in aging patterns require tailored policy responses. To effectively address the consequences of an aging population, it is crucial to understand the spatial dimensions of this phenomenon. In addition to broad national policies, targeted interventions tailored to the specific needs and conditions of each region are essential. Developing and implementing these interventions requires the use of spatial data, employing modern methods of analysis and presentation.

Apart from births and deaths, the population structure of Greece has been shaped by movements, both internal and international (Kotzamanis 2021). Internal migration, mostly driven by economic inequalities and employment opportunities, has led to a strong redistribution of the population within the country, while migratory waves, both incoming and outgoing, have reshaped the country's demographic composition.

The demographic shifts observed in Greece over the past two decades are not isolated events but are related to broader social, economic, and political developments spanning the last 40 years. Demographic changes occur slowly and their consequences are not immediately reflected by the indicators. However, certain events can accelerate these changes. The economic crisis in the late 2000s, which severely affected the Greek economy and led to austerity measures and structural reforms, had a lasting impact on population dynamics (Kotzamanis et al. 2017). High unemployment rates, especially among young people, have affected migratory flows, with many Greeks seeking opportunities abroad in search of better prospects. In addition, the economic recession had an impact on family planning decisions, contributing to lower fertility rates and changes in household structures.

Besides socio-economic variables, the spatial distribution of the population in Greece is also influenced by environmental factors such as topography, climate, and natural resources. Coastal areas and islands, for example, may attract more inhabitants due to their favorable climate and access to marine resources, leading to a higher population density. This demographic shift is often influenced by regional economic and lifestyle factors. Conversely, mountainous or remote areas may experience depopulation or population aging due to limited economic opportunities and infrastructure. Therefore, environmental assessments are fundamental in understanding the geographic heterogeneity of the population structure in Greece and identifying areas that may be vulnerable to demographic challenges or environmental risks (Kalogeropoulos 2020; Kalogeropoulos et al. 2023).

Mapping and analyzing the population structure in Greece over the last twenty years provides valuable information on the demographic evolution of the country and the challenges and opportunities it presents. Focusing on trends in population aging, migration, and regional disparities, researchers can identify areas that need targeted interventions and inform evidence-based policy decisions. This approach enables a deeper analysis of demographic dynamics at the local level. Understanding the complex interplay of economic, social, cultural, and environmental factors is essential for developing integrated strategies that promote sustainable development and social cohesion across the country. These insights help to inform data-driven decision making at local and national levels. Therefore, mapping census data are another way to disseminate these data (van Elzakker et al. 2003; Kalogeropoulos 2020).

In this paper, a multidisciplinary approach that integrates demographic data using spatial analysis techniques such as R and GIS at the municipality level is proposed (Wardrop et al. 2018). For the analysis and mapping of the population structure in Greece, a new method to capture population aging was used, as proposed by Kashnitsky and Schöley (Kashnitsky and Schöley 2018). This approach maps age structures with a tripartite color coding system, assigning colors to three main age groups: >15, 15–65, >65 years. Each municipality is assigned a specific color according to its age structure. The color coding has been modified to retrieve data from Greek databases, allowing the population structure of each municipality to be visualized accurately. This paper contributes to geodemography by presenting and indicating a visualization technique that boosts the precision of demographic analysis, providing policy makers with valuable information to better address local demographic challenges and adapt policies to specific regional needs. Furthermore, by utilizing data from the three most recent censuses in Greece, this study provides a valuable longitudinal perspective on population aging trends.

2. Methodology

2.1. Data Used

The data used in this paper come from the population censuses conducted by the Hellenic Statistical Authority (ELSTAT) for the years 2001, 2011, and 2021. Specifically, data on the number of people in the age groups 0–14, 15–65, and >65 years at the municipality level were used (for 2001 and 2011, data were reduced to the data for the 332 municipalities present in 2021). The next Figure (Figure 1) presents the study area, Greece (regions of).

2.2. The Used Methodology

For the purposes of studying and mapping the age structure of the Greek population, a new approach was used to investigate the diversity of population aging. This approach was originally proposed in Kashnitsky and Schöley work (Kashnitsky and Schöley 2018). This method has since been adapted for various regional studies. In these studies, the population structure of Europe is investigated at the regional level. Instead of any single summary measure for aging, the entire population age structure is mapped using a tripartite color coding system (palette)—a technique that maximizes the amount of information conveyed by colors (Figure 2). This figure shows the three main categories to be mapped and relates to the age groups <15, 15–65, and >65 years. The colors purple, blue, and yellow are assigned to these groups, respectively. Depending on the population structure, each spatial unit (municipality) is given a specific mixture of the above colors depending on its age structure (each municipality is shown as a point in the palette), as shown in Figure 2. This means that the closer to blue, the greater the relative presence of a working-age population in this municipality. Intermediate shades represent a mix of these age groups. The closer to purple, the younger the population (% of children under 15 years old), and the closer to yellow, the more aged the population of the municipality. All the intermediate colors visualize the remaining percentages of the population structure of each municipality. Each municipality is presented as a black dot within the color palette.

Figure 1. The study area—Greece (regions of).

With this approach, each element of a three-dimensional data array composition, such as the three age groups here, is represented by a unique color. This method enables the visualization of complex demographic data in a clear and intuitive way. The use of color mixing to encode multidimensional data into a single feature has been proposed by several authors (Dorling 1991; Kashnitsky et al. 2017; Kashnitsky and Schöley 2018). Since then, the approach has been used to map electoral outcomes in a three-party system, the composition of the labor force by sector, soil textures, the composition of Arctic sea ice cover, and causes of death (Schöley and Willekens 2017). This method has proven to be a versatile way to represent diverse datasets through visual means. In this paper, color coding was used to investigate differences in population structures in Greece by modifying the R code freely provided by Kashnitsky and Schöley (Kashnitsky and Schöley 2018). Thus, while their code was directly linked to the corresponding Eurostat data (descriptive and spatial), in this paper it was modified to retrieve the corresponding data for Greece from indicated databases. This ensures an accurate representation of demographic proportions in the visualizations. The percentages of each category are superimposed on the mapping color palette to give each municipality the corresponding color representing its population structure.

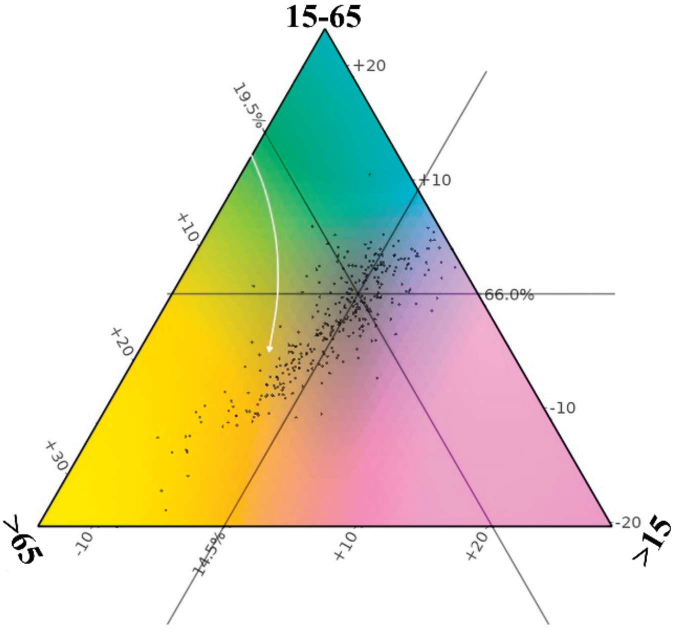

Figure 2. Color mapping palette (each black dot is a municipality).

2.3. Software Used

The data analysis was conducted using R software (version 4.1.3). Specific packages used within R included 'tidyverse' for data manipulation and visualization, 'rgdal' for handling spatial data, and 'ggplot2' for creating plots, as provided by Kashnitsky and Schöley (Kashnitsky and Schöley 2018). We avoided using the packages 'sf', 'stars', and 'terra' to prevent potential comparability issues with other Tricolore publications. Then, the maps extracted from R were imported into ArcGIS Pro 3.2 (ESRI, Redlands, CA, USA) to be supplemented with additional data such as a layer representing the regions of Greece.

3. Results and Discussion

Analyzing primary data from the three most recent censuses reveals some key trends in the evolution of the country's population structure. Notably, the 15–64 age group has experienced an overall decline. This indicates a reduction in the proportion of the population within this working-age group between 2001 and 2021. In contrast, the over 65 age group has shown an overall increase, reflecting a rising number of older adults during the same period. The 0–15 age group presents a more complex picture, with some areas experiencing declines and others seeing increases. However, the general trend suggests a decrease in this younger demographic, as negative changes outnumber positive ones.

Overall, these findings indicate a demographic shift towards a more aged population between 2001 and 2021, characterized by a decline in the working population (15–64 years) and a rise in the older population (over 65 years). In addition, there appears to be a slight decrease in the proportion of the population aged 0–15 years, although the trend in this age group is less consistent.

The following maps eloquently depict the changes in the population structure in Greece overtime, at the municipality level.

The map in Figure 3 illustrates the changes in the country's population structure following the 2001 census, focusing on the level of municipalities and showing the regional boundaries. The color palette reveals that the average population structure, or intersection, is found in regions with a lower proportion of elderly individuals and a higher proportion of adults.

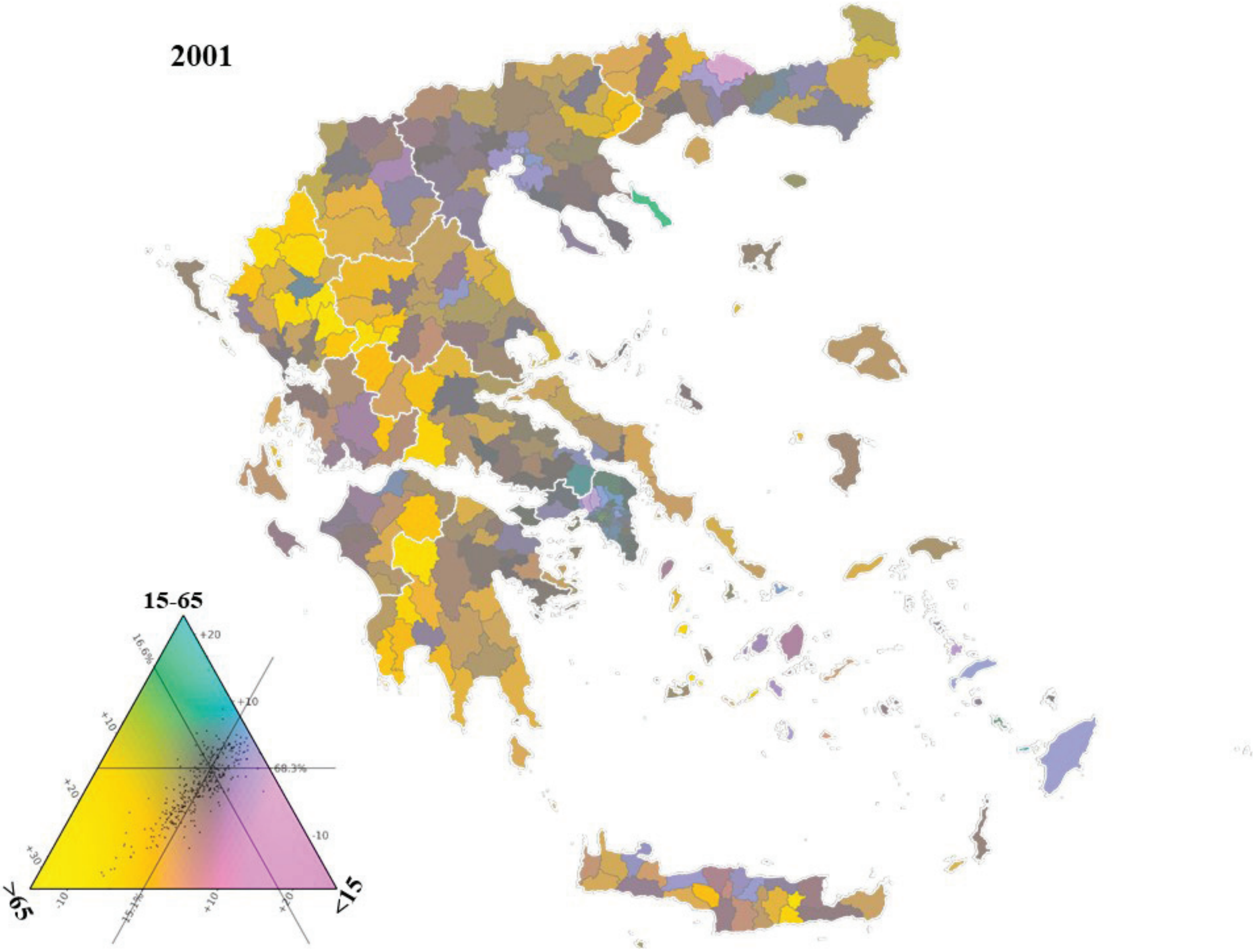

Figure 3. Population structure (2001).

Additionally, there is a noticeable dynamic in the population structure of Greece's two major urban centers: the areas surrounding the Municipality of Athens (Athens Metropolitan Center—Attica Region) and the Municipality of Thessaloniki (shaded in purple-blue—Central Macedonia Region). This trend is understandable on a macroeconomic level, as these centers house a significant portion of the country's active workforce, which drives employment opportunities.

Furthermore, there is a distinct pattern, forming an arc from the municipalities on the northwestern edge of Greece (e.g., Konitsa, Pogoni, Filiates) within the Epirus Region, extending to the westernmost part of the Peloponnese Region (e.g., Pylos-Nestoros and Messini). These areas are characterized by a notably aging population (over 65 years old), with exceptions seen in the capitals and larger urban centers of the respective regional units, such as Ioannina (R.U. Ioannina–Epirus Region), Agrinio (R.U. Agrinio–Central Greece Region), Patras (R.U. Achaia–Western Greece Region), and Kalamata (R.U. Messinia–Peloponnese Region).

The map in Figure 4 shows the population structure of the country after the 2011 population census.

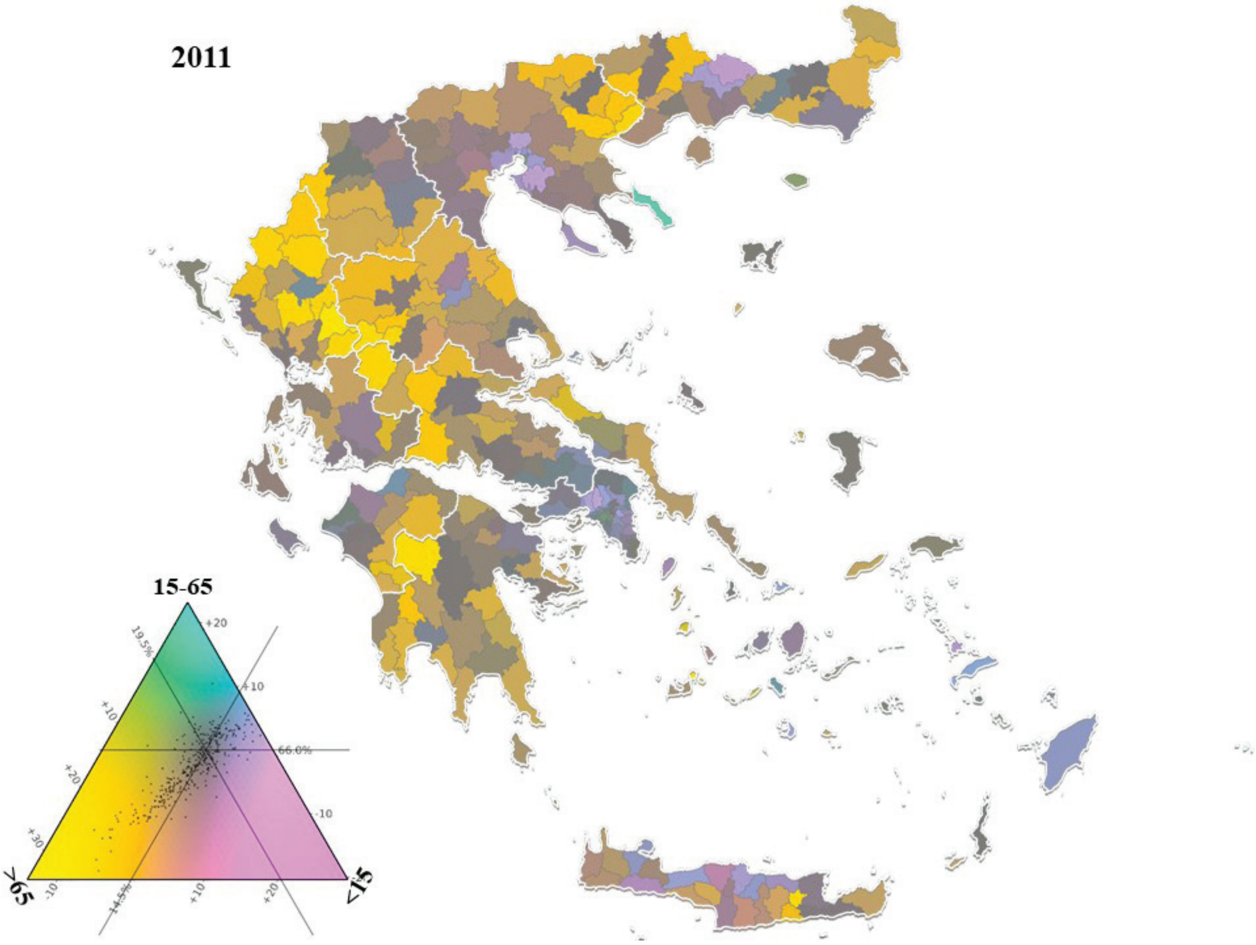

Figure 4. Population structure (2011).

Figure 4 displays population data similar to that in Figure 3 but focuses on the aged population, highlighted in yellow shades, which is primarily located in Western Greece. This map clearly illustrates the shift towards a higher proportion of individuals aged 65 and over. Out of 332 municipalities, only 25 have experienced a decrease in this age group, while the remaining municipalities have seen increases. Notable examples include the municipalities of Amphipolis (Central Macedonia Region), Nestoriou (Western Macedonia Region, and Visaltia (Central Macedonia Region), which have experienced increases of over 10%, and Andritsaina-Krestenon (Western Greece Region), Sintiki (Central Macedonia Region), Central Tzoumerka (Epirus Region), and Agrafa (Central Greece Region), where the increase in the aged population exceeds 9%.

The following figure, Figure 5, depicts the population structure of the country based on the 2021 census.

As shown on the map above, there is a clear shift towards the above 65 years of age group. The data reveal a consistent pattern: the population aging observed between 2001 and 2011 is mirrored in the data from the 2011 and 2021 censuses. The latest census continues to reflect the trend in population aging observed over the last 20 years, mainly in Western Greece. The data reveal a consistent pattern: decline in the younger age group (0–15 years), minimal changes in the working-age population, and a noticeable increase in the elderly (over 65 years). This trend is evident throughout Greece and highlights broader demographic shifts, such as falling birth rates and an aging population. Specifically, cities like Komotini and Alexandroupoli (Eastern Macedonia and Thrace Region) in eastern

Greece have seen relatively small reductions of 1% to 3% in the younger population. These decreases are often accompanied by a modest rise in the elderly population. For instance, the older people living in Komotini and Alexandroupoli rose by almost 3–4%. On the other hand, there are also many municipalities where changes are far more pronounced, e.g., Grevena (Western Macedonia Region), Dodoni and Zagorio (Epirus Region). Huge drops in the 15–65 age group (10% or more) and large increases in those over sixty are prominent in these areas. Depopulation, due to the outward migration of the younger generations, has aggravated the rapid aging process. For example, in Arriana, the older population grew by 9.82%, while in Iasmos the above increase reached 11.60% (Eastern Macedonia and Thrace Region). Thus, this shift in demographics will require major changes to public policy, healthcare, housing and accommodation, and social services for the elderly.

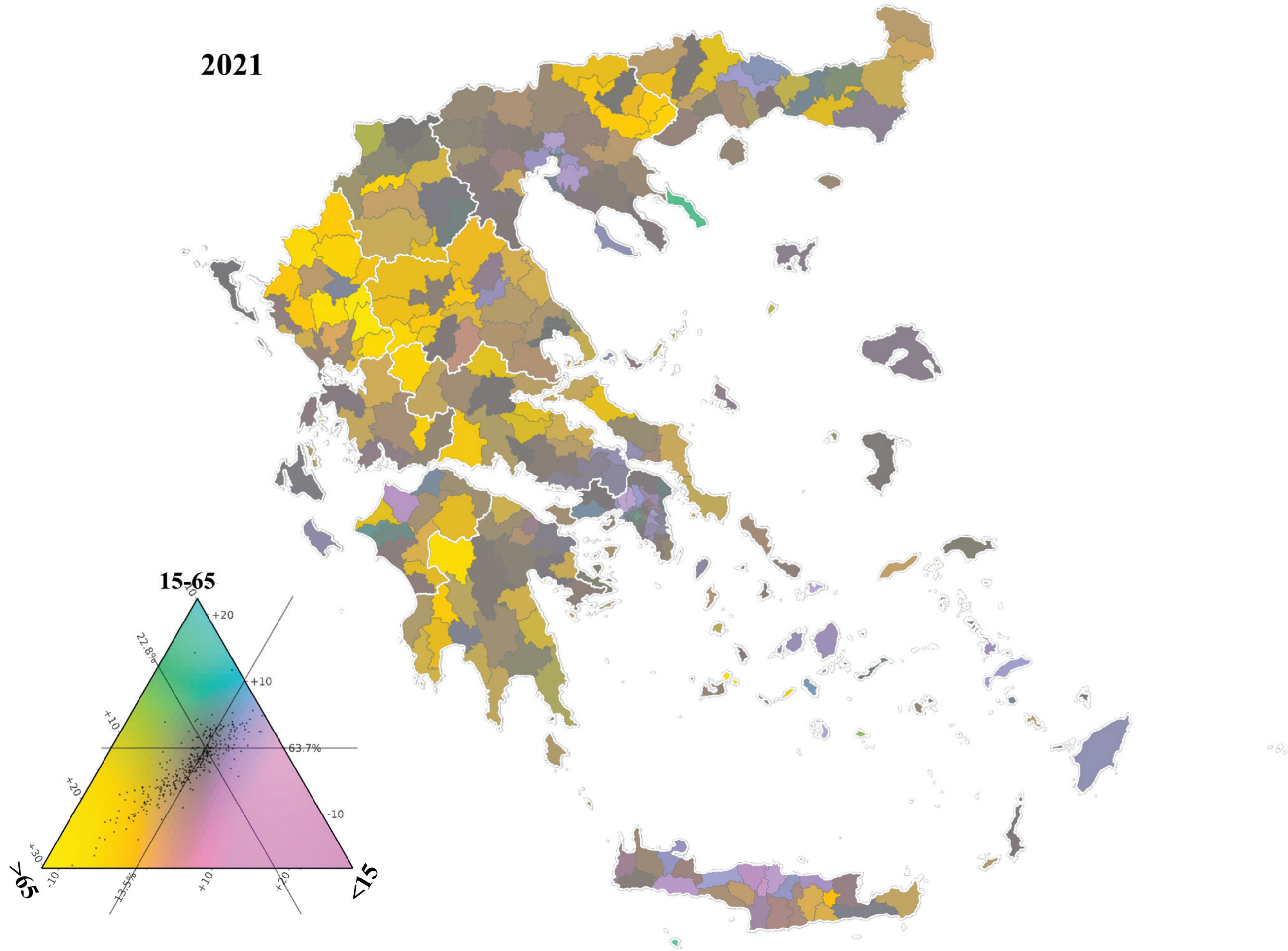

Figure 5. Population structure (2021).

Examining the whole period over the last 20 years (three censuses), the 0–15 age group decreased in almost all of the municipalities, which raises concerns about the future population and economic health. Municipalities like Myki (Eastern Macedonia and Thrace Region) and Aminteo (Western Macedonia Region) saw big drops of 8.58% and 10.28%. This could directly affect the quality and quantity of services provided to young persons (local schools, youth programs, and jobs) causing a vicious cycle that further aggravates depopulation and aging.

The above figures show changing population patterns that, if not taken into consideration, may undermine regional development. The decrease in young and working-age people, along with more old people, could make it hard to keep the economy going and provide social services. Local leaders might need to come up with new ideas to deal with these changes. They might try to bring in more young people or increase the number of babies being born, while also helping older people more.

This is, of course, a consequence of the decrease in birth rates, the flight of a large part of the economically active population in the years of the economic recession and vice versa, the increase in the survival rate of elderly people, etc.

Due to the geographical nature of census data, maps are a critical element in conducting a census or survey, but also in the dissemination of the results. Therefore, mapping is a very important function of statistical services. Maps are used both by census takers, at the survey-recording stage of data collection, and in print and electronic publications, as a supplement to statistical data (Bower 2010).

The decision to adopt this particular color-coding method, originally proposed by Kashnitsky and Schöley, was due to its ability to visually capture the complexity of the age structure of the population in a single, intuitive image. This approach allows for a holistic longitudinal comparison of municipalities. In comparison with other methods, such as spatial maps, the tripartite palette approach provides information not only on age groups but also on the balance between them. Given the aging population in Greece, the method offers clarity and depth in its perspective, thus facilitating policy making. Alternative ways of presenting the population structure would require many more maps in order to achieve the same level of detail. However, the chosen technique compresses the multidimensional age data into a single visual effect.

Kashnitsky and Schöley's R code was modified in order to achieve compatibility with Greek demographic data. The original code analyzed data from Eurostat databases. This link was modified so that the data were extracted from the database created for the needs of the study. Through testing, the way in which the spatial data were extracted was also modified to ensure that the tripartite mapping of the population structure by municipality was accurately mapped.

Traditionally, the role of maps in a census has been to support the enumeration and presentation of residents and dwellings at all stages of the census process (before, during and after the census) and to present the results of this on a map. The rapid technological development that has taken place in recent years (both in GIS science and cartography) has significantly expanded this role. In addition to the more efficient production of population census maps and thematic census maps, GIS now plays a key role in familiarizing society with the census process and in the more thorough analysis of the data it provides (United Nations 2000). The cartographic presentation of census results is a powerful tool as it can support the identification of local patterns of important demographic and social indicators. As such, maps are an integral part of management policies in the public and private sectors. Moreover, highlighting spatial variations is important, as it is imperative and necessary in economic and social planning on the part of the state at local and regional levels (Kotzamanis and Pappas 2000; Pappas 2001).

4. Conclusions

The present study investigated the evolution of population structures in Greece during the last two decades, based on data from population censuses. The main emphasis was placed on mapping and analyzing population aging at the local level, specifically within municipalities. To achieve this objective, the study used a new approach that adopts a three-color coding/grading system to visually represent the age structure in each municipality.

The findings reveal notable variations in population aging across different regions of the country. Some municipalities have already experienced higher levels of aging, while in others aging is progressing more rapidly compared to the national average. These disparities may be influenced by factors such as regional economic conditions, migration trends or access to healthcare services. The use of tripartite color coding has proved particularly effective in visualizing these differences, making it easier to identify areas that require targeted attention.

The study employed a relatively new methodological approach that utilizes trivariate color coding to represent age structures. This technique has been highly effective in depicting complex population structure data and highlighting spatial variations. By using color coding to illustrate three distinct age groups (0–14, 15–65, and over 65 years), the method presents demographic information in a clear and visually engaging manner, enhancing our understanding of local demographic trends.

The insights provided by the study are valuable for policymakers, researchers, and local communities, aiding in the development of targeted strategies to address the challenges of an aging population. Additionally, the tripartite color-coding methodology can be applied to other demographic or socio-economic data, facilitating the visualization of complex information and the identification of spatial patterns. The study provides a lot of information on demographic developments and variations in Greece. Firstly, the visualization technique used revealed distinct patterns of population aging at a very detailed level, thus highlighting the municipalities experiencing the fastest demographic changes. Conversely, municipalities with younger populations are highlighted, suggesting emerging opportunities for investment in youth-oriented education and infrastructure. In addition, the analysis reveals those transition zones where demographic profiles are changing, indicating areas that may need to be targeted for the implementation of targeted policies. Mapping using this method therefore provides the necessary knowledge for the implementation of appropriate policy interventions.

Despite the valuable insights provided by this study, there are important limitations that need to be considered. One of these is the reliance on data from only the three most recent censuses. This means that long-term trends in the population structure may not be detectable. The method used implies the use of detailed data. This means that it should be used according to the number of spatial entities used at any one time. Finally, since the input data are only population data, it is assumed that the socio-economic conditions of each region are not taken into account and therefore these should be used in the discussion of the results.

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References

Andreopoulos, Panagiotis, Fragkiskos G. Bersimis, Kleomenis Kalogeropoulos, and Alexandra Tragaki. 2023a. Recent Changes in Human Mortality: The Case Study of Greece. In *Quantitative Demography and Health Estimates*. Edited by C. H. Skiadas and C. Skiadas. The Springer Series on Demographic Methods and Population Analysis. Cham: Springer Nature Switzerland, vol. 55, pp. 217–31. ISBN 978-3-031-28696-4.

Andreopoulos, Panagiotis, Kleomenis Kalogeropoulos, Alexandra Tragaki, and Nikolaos Stathopoulos. 2021. Could Historical Mortality Data Predict Mortality Due to Unexpected Events? *ISPRS International Journal of Geo-Information* 10: 283. [CrossRef]

Andreopoulos, Panagiotis, Kleomenis Kalogeropoulos, and Alexandra Tragaki. 2023b. Analysis and mapping of mortality data using probabilistic distributions in Millennium Greece. In *Demographic Projections. Modern Research Approach and Mapping*. Volos: University Publications of Thessaly, pp. 115–27, ISBN 978-960-9439-91-6.

Baffour, Bernard, Thomas King, and Paolo Valente. 2013. The Modern Census: Evolution, Examples and Evaluation. *International Statistical Review* 81: 407–25. [CrossRef]

Bower, Kaile. 2010. Looking Back and Ahead: A History of Cartography at the Census Bureau and What the Future Holds. Paper presented at A Special Joint Symposium of ISPRS Technical Commission IV & AutoCarto in Conjunction with ASPRS/CaGIS 2010 Fall Specialty Conference, Orlando, FL, USA, November 15–19.

Dorling, Danny F. L. 1991. The Visualisation of Spatial Social Structure. Ph.D. thesis, University of Newcastle upon Tyne, Newcastle upon Tyne, UK.

Kalogeropoulos, Kleomenis. 2020. The Geographical Aspect of the Geodata of the National Population Censuses. Mapping—Creation of Modern Spatial Data Infrastructures with the Use of Geoinformatics. Ph.D. thesis, Department of Gepgraphy, Harokopio University, Harokopio, Greece.

Kalogeropoulos, Kleomenis, Panagiotis Andreopoulos, A. Tsatsaris, and Christos Chalkias. 2023. Historical Geography, Geodemography and Mapping of Population Censuses in Greece. In *Demographic Projections. Modern Research Approach and Mapping*. Volos: University publications of Thessaly, pp. 69–84, ISBN 978-960-9439-91.

Kashnitsky, Illya, and Jonas Schöley. 2018. Regional Population Structures at a Glance. *The Lancet* 392: 209–10. [CrossRef] [PubMed]

Kashnitsky, Illya, Joop De Beer, and Leo Van Wissen. 2017. Decomposition of Regional Convergence in Population Aging across Europe. *Genus* 73: 2. [CrossRef] [PubMed]

Killick, Lynn, Hazel Hall, Alistair S. Duff, and Mark Deakin. 2016. The Census as an Information Source in Public Policy-Making. *Journal of Information Science* 42: 386–95. [CrossRef]

Kotzamanis, Byron. 2009. Reflections on the course of fertility and fecundity in Greece, reason and counterargument. In *The Demographic Challenge, Facts and Stakes*. Volos: University Publications of Thessaly.

Kotzamanis, Byron. 2021. *Demographic Developments and Challenges*. Athens: Institute of Small Enterprises of the General Confederation of Professionals, Craftsmen and Traders of Greece. ISBN 978-618-5025-78-6.

Kotzamanis, Byron, Anastasia Kostaki, D. Balourdos, and Alexandra Tragaki. 2018. *The Demographic Developments/Prospects of the Population of Greece and Proposals for the Basic Principles of a Demographic Policy*. Athens: Small Business Institute, pp. 24–186.

Kotzamanis, Byron, and Vasileios Pappas. 2000. *Spatial Implications of Demographic Data*. Volos: University Publications of Thessaly. ISBN 960-8029-13-9.

Kotzamanis, Byron, Pavlos Baltas, and Anastasia Kostaki. 2017. The Trend of Period Fertility in Greece and Its Changes During the Current Economic Recession. *Population Review* 56: 2. [CrossRef]

Landry, Adolphe. 1945. *Traite de Demographie*. Paris: Payot.

MacDonald, Alphonse L. 2019. The Population Census: Counting People Because They Count. In *The Palgrave Handbook of Global Health Data Methods for Policy and Practice*. Edited by S. B. Macfarlane and C. Abou Zahr. London: Palgrave Macmillan UK, pp. 105–23, ISBN 978-1-137-54983-9.

Matthews, Stephen, and Daniel M. Parker. 2013. Progress in Spatial Demography. *Demographic Research* S13: 271–312. [CrossRef] [PubMed]

Pappas, Vasileios. 2001. Spatial implications of demographic data. Selections from a scientific conference at the University of Thessaly. *Geographies* 2: 113–17.

Ricciato, Fabio, Albrecht Wirthmann, and Martina Hahn. 2020. Trusted Smart Statistics: How New Data Will Change Official Statistics. *Data & Policy* 2: e7. [CrossRef]

Rovolis, Antonis, and Alexandra Tragaki. 2006. Ethnic Characteristics and Geographical Distribution of Immigrants in Greece. *European Urban and Regional Studies* 13: 99–111. [CrossRef]

Schöley, Jonas, and Frans Willekens. 2017. Visualizing Compositional Data on the Lexis Surface. *Demographic Research* 36: 627–58. [CrossRef]

Tragaki, Alexandra, and Katia Lasaridi. 2009. Temporal and Spatial Trends in the Sex Ratio at Birth in Greece, 1960–2006: Exploring Potential Environmental Factors. *Population and Environment* 30: 114–28. [CrossRef]

UNFPA. 2002. *Population and Housing Census: Strategies for Reducing Costs*. New York: United Nations Population Fund. ISBN 978-0-89714-649-4.

United Nations, ed. 2000. *Handbook on Geographic Information Systems and Digital Mapping*. Studies in Methods. New York: United Nations. ISBN 978-92-1-161426-8.

United Nations, ed. 2001. *Handbook on Census Management for Population and Housing Censuses*. Studies in Methods, Rev.1. New York: United Nations. ISBN 978-92-1-161429-9.

van Elzakker, Corné P. J. M., Ferjan Ormeling, Barend J. Köbben, and Daisy Redido-Cusi. 2003. Dissemination of Census and Other Statistical Data Through Web Maps. In *Maps and the Internet*. Amsterdam: Elsevier, pp. 57–75, ISBN 978-0-08-044201-3.

Vollset, Stein E., Emilly Goren, Chun-Wei Yuan, Jackie Cao, Amanda E. Smith, Thomas Hsiao, Catherine Bisignano, Gulrez S. Azhar, Emma Castro, Julian Chalek, and et al. 2020. Fertility, Mortality, Migration, and Population Scenarios for 195 Countries and Territories from 2017 to 2100: A Forecasting Analysis for the Global Burden of Disease Study. *The Lancet* 396: 1285–306. [CrossRef] [PubMed]

Wardrop, Nicola A., Warren C. Jochem, Tomas J. Bird, H. R. Chamberlain, Donna Clarke, David Kerr, Linus Bengtsson, Sabrina Juran, Vincent Seaman, and Andrew J. Tatem. 2018. Spatially Disaggregated Population Estimates in the Absence of National Population and Housing Census Data. *Proceedings of the National Academy of Sciences USA* 115: 3529–37. [CrossRef] [PubMed]

Warren, Robert. 2014. Democratizing Data about Unauthorized Residents in the United States: Estimates and Public-Use Data, 2010 to 2013. *Journal on Migration and Human Security* 2: 305–28. [CrossRef]
Yildiz, Dilek, and Peter W. F. Smith. 2015. Models for Combining Aggregate-Level Administrative Data in the Absence of a Traditional Census. *Journal of Official Statistics* 31: 431–51. [CrossRef]

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Regional Workforce Dynamics in West Virginia: Insights from Shift-Share and Location Quotient Analysis

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Abstract: West Virginia, home to approximately 1.77 million residents, has been grappling with significant economic challenges characterized by persistent poverty and sluggish growth. Despite ongoing development efforts, the state's Gross State Product (GSP) has seen only a modest increase of 0.1% over the past five years, reaching USD 71.7 billion, while the unemployment rate remains at 4.0%. The annualized employment growth rate of 0.7% lags behind the national average, and only about 54% of West Virginia's adult population is either employed or actively seeking employment, resulting in one of the lowest labor force participation rates in the nation. In contrast, certain industrial sectors, such as healthcare, social assistance, retail trade, and accommodation and food services, have shown intermittent growth at the county and regional levels. To explore the unique characteristics and significance of these regions in relation to employment growth, this study examines regional employment patterns in West Virginia from 2001 to 2020, focusing on the main regions of the state: Metro Valley, Mid-Ohio Valley, New River/Greenbrier Valley, Mountain Lakes, and Potomac Highlands. Utilizing shift-share and location quotient (*LQ*) analyses, this research identifies the sectors driving regional employment and assesses their performance. Key findings reveal strong sectoral performance in mining, manufacturing, and finance in the Mid-Ohio Valley; wholesale trade, transportation, and utilities in the Metro Valley; agriculture and administrative services in the New River/Greenbrier Valley; agriculture and manufacturing in the Potomac Highlands; and scientific services, healthcare, and utilities in the Mountain Lakes region. Based on these insights, this study recommends targeted policy interventions to address regional disparities, enhance sectors with significant short- and long-term benefits, and foster balanced economic development across the state.

Keywords: shift-share analysis; location quotient analysis; economic growth

1. Introduction

West Virginia, nestled in the Appalachian region of the United States, is one of the least populous states, with a population of 1,775,513. The state faces negative annualized growth and ranks 50th among U.S. states in terms of growth rate. Its gross state product (GSP) has reached USD 71.7 billion, reflecting a modest 0.1% increase over the past five years. Despite continuous efforts to stimulate economic development, the unemployment rate remains at 4.0%, underscoring ongoing economic challenges (IBISWorld 2024). West Virginia has long struggled with economic diversification and population decline, exacerbated by the fact that a significant portion of its residents are aged 65 and older. Given the state's weaker economic performance compared to neighboring states and the broader U.S. economy, net migration has increasingly contributed to its population decline.

The state's annualized employment growth rate of 0.7% lags behind the national average, and only about 54% of West Virginia's adult population is either employed or actively seeking employment, making it one of the lowest labor force participation rates in the nation. This presents a considerable obstacle to long-term economic prosperity (Bureau of Business and Economic Research, John Chambers College of Business and Economics, West Virginia University 2020). Additionally, factors such as poor health outcomes and limited human capital have further hindered labor force participation, affecting the state's capacity to expand its workforce and improve economic prospects.

West Virginia's unemployment rate has fluctuated in recent years, reflecting both economic difficulties and demographic trends (IBISWorld 2024). However, certain industrial sectors, such as the service sector, have experienced intermittent growth at the county and regional levels. The declining unemployment rate in regions like North Central and the Eastern Panhandle is partly attributed to relatively healthy economic conditions and growth in industries beyond traditional sectors, bolstered by infrastructure development. In addition to these, emerging sectors like healthcare, social assistance, retail trade, and accommodation and food services have contributed to employment growth in various regions of the state.

When examining West Virginia's five key regions—Metro Valley, Mid-Ohio Valley, New River/Greenbrier Valley, Potomac Highlands, and Mountain Lakes—specific industrial sectors emerge as potential drivers of future growth. A regional economy is composed of diverse firms and industries, each with distinct growth patterns and economic potential. Sectoral expansions or contractions can significantly impact overall economic performance (McNamara 1991; Bartik 2004; Herath et al. 2013). Therefore, understanding the competitive advantages of different regions and sectors is critical for shaping effective policy and investment strategies (Melachroinos 2002). This is particularly important for less-developed regions like West Virginia, where strategic investments could have a disproportionately positive effect on economic development.

Given the limited studies addressing industrial sectors, employment shifts, and their impacts on the regions of West Virginia, this study aims to answer the following research question:

- How have various industrial sectors contributed to West Virginia's economic progress over the past two decades, considering the state's economic challenges and demographic shifts, and what policy measures can be identified to enhance future economic growth?

With the significance of the above research questions, this study has the following objectives:

- To analyze industrial growth patterns in key sectors of West Virginia.
- To evaluate the regional economic impacts of sectoral changes on employment.
- To identify policy recommendations that promote economic growth and address challenges in West Virginia's economy.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature, providing a foundation for the study. Section 3 outlines the data and methods used in the research. Section 4 presents the empirical results along with the analysis. Finally, Section 5 concludes with key findings and policy recommendations.

2. Literature Review

2.1. Shift-Share and LQ Applications

In regional economic analysis, various methods such as shift-share analysis and location quotient (LQ) have been extensively used to understand economic dynamics and competitive advantages. Shift-share analysis, developed in the 1940s by Daniel Creamer and later popularized by Dunn in 1960, decomposes regional economic changes into three components: national, industry, and regional effects (Dunn 1960). This method has been widely applied to examine geographical shifts in economic activity, making it valuable for assessing regional competitiveness over time and across various fields, including regional and political economy, urban studies, and marketing (Knudsen 2000; Shi and Yang 2008).

Research has demonstrated the utility of shift-share analysis in diverse contexts. For instance, the technique has been employed to forecast regional growth, analyze policy effects, and support strategic community planning (Selting and Loveridge 1994). It has also been used to predict regional investment decisions (Ireland and Moomaw 1981), measure employment growth (Barff and Knight 1988), and assess economic impacts across different regions (Herath et al. 2013; Herath Bandara 2024). Notably, recent applications include evaluating resource regions for mineral exploitation (Sablin et al. 2018), analyzing international trade sensitivity (Markusen et al. 1991), and studying regional resilience during economic crises (Giannakis and Bruggeman 2015). Shift-share analysis continues to provide valuable insights into regional economic dynamics across various sectors and geographic scales (Dembińska et al. 2022). In recent years, it has also been utilized to assess sustainable development in Polish regions (Cieślak et al. 2019), examine regional growth in Romania following EU accession (Goschin 2014), and explore green investment trends in China (Sheng et al. 2021).

Location quotient (*LQ*) is another crucial tool used to assess regional economic specialization. It compares a region's concentration in a particular industry to that of a broader reference area, typically on a national scale, to highlight sectors where the region may have a comparative advantage (Morrissey 2014). *LQ* is widely used in regional economic analysis and policymaking. Recent studies have applied *LQ* to identify hot spots for industrial reshoring (Sarder et al. 2018), differentiate between urban and rural labor markets (Franconi et al. 2024), and evaluate regional production multipliers (Morrissey 2014). *LQ* has also been used to determine dominant economic sectors in specific regions, such as those connected to infrastructure projects (Sampe et al. 2023), and to track changes in industrial concentration over time (Prats and Ramirez 2018). While *LQ* is effective in highlighting regional strengths and sectoral advantages, it does have limitations. These include sensitivity to extreme values, sparsity, and size effects in smaller regions (Franconi et al. 2024). Adjusted *LQ* values have been proposed to address these issues and improve classification robustness. Overall, both shift-share analysis and *LQ* remain essential tools for understanding and enhancing regional economic performance, each offering unique insights into regional growth, competitiveness, and specialization.

2.2. Context and Relevance of the Study Area

2.2.1. Agricultural Sector

The agricultural sector in West Virginia significantly contributes to the state's economy, generating an average of USD 800 million annually. Despite this substantial input, the sector has seen a slight decline in employment numbers in recent years. This trend is concerning, especially in counties such as Greenbrier, Pendleton, Hardy, Monroe, and Preston, which collectively hold the most farmland by acreage in the state (Sperow 2023; West Virginia Agriculture 2023). This decline mirrors broader rural economic patterns, where high agricultural productivity persists despite decreasing workforce participation.

Historically, West Virginia's farmland was dedicated to corn and small grains, covering 1.2 million acres by the late 19th century. Today, about 40% of corn is harvested for silage, and soybean production has shifted to a cash market. Fruit production, including apples and peaches, has notably decreased; most apples are now processed, and peaches are mostly sold fresh (Sperow 2023). Currently, hay is the leading crop, contributing 2% to the state's agricultural receipts. The state also grows apples, corn, wheat, soybeans, peaches, and tobacco (Atitwa 2020). Grass, primarily used for permanent pastures, covers nearly one-third of the 3.6 million acres of farmland. Livestock production, including broilers, cattle, turkeys, sheep, hogs, chickens, and farm-raised fish, dominates, accounting for 82% of agricultural output (Atitwa 2020; Sperow 2023).

In response to industry challenges, such as those faced by the dairy sector, West Virginia has streamlined regulations for small producers by transferring authority to the WVDA. This regulatory shift supports new market opportunities for non-hazardous foods and milk, addressing sector-specific issues and fostering growth (Leonhardt 2021).

2.2.2. Manufacturing Sector

West Virginia's manufacturing sector presents a complex landscape, marked by both positive growth and significant challenges. Chemical manufacturing, a dominant force within this sector, accounts for 20% of manufacturing jobs and nearly 40% of the sector's economic output. This industry includes the production of adhesives, plastics, pharmaceuticals, and industrial chemicals. However, the manufacturing sector in West Virginia is diversified, encompassing motor vehicles, primary metals, petroleum and coal products, and more. Despite its challenges, the sector constituted 10.25% of the state's total output and employed 6.48% of the workforce in 2018, generating USD 7.94 billion in total output (Fauber 2022; Miller 2022). Small businesses are also a vital component, representing 76% of total manufacturing exporters in the state (Atitwa 2020). These data underscore the importance of manufacturing to the state's economy, aligning with national trends that highlight the sector's role in economic resilience and job creation.

Recent developments in West Virginia's manufacturing sector highlight both growth and challenges. Procter & Gamble has significantly expanded in Berkeley County with a USD 500 million facility, boosting local employment to over 1400 and advancing the production of soaps and cleaning products (Bureau of Business and Economic Research 2022). Meanwhile, the sector faces setbacks, such as Viatris' closure of the Mylan facility in Morgantown, leading to anticipated job losses of over 1400 and heightened uncertainty (Bureau of Business and Economic Research 2022).

The state is also beginning to see growth in clean-tech manufacturing. GreenPower is setting up a plant for electric buses near Charleston, and Sparkz plans to build a Gigafactory in Taylor County for next-gen EV batteries. Additionally, Berkshire Hathaway Energy's renewable energy microgrid at the former Century Aluminum site could attract more clean-tech manufacturers seeking cost-effective energy solutions (Bureau of Business and Economic Research 2022).

2.2.3. Construction Sector

The construction sector in West Virginia is crucial for job creation, income, and tax revenue, affecting related industries like manufacturing, warehousing, transportation, and real estate. Over the past two decades, the sector has experienced significant fluctuations. Notably, workforce levels declined sharply in late 2018 due to various industry challenges (West Virginia Construction and Building Trends 2023).

Between mid-2012 and mid-2013, the state started over 2000 new single-family homes, a 19% increase from the previous year but still below 2006 levels. Apartment construction peaked in 2006–2007 with over 2000 units but dropped to fewer than 300 units by mid-2013. Non-building construction, including infrastructure projects, showed a 46% decrease in value in early 2013 compared to 2012, with the exception of waterway projects.

In 2022, West Virginia's non-residential construction totaled USD 500.6 million (45th among U.S. states), while residential construction reached USD 18.1 million (41st). The state issued 3929 building permits in 2022, reflecting a 7.3% annualized growth rate from 2017 to 2022 (West Virginia Construction and Building Trends 2023). These fluctuations highlight broader economic shifts, reflecting both cyclical and long-term structural changes in the state.

2.2.4. Mining Sector

The mining sector, once a cornerstone of West Virginia's economy, has seen a dramatic decline in workforce numbers, particularly in coal mining. Historical data reveal a sharp drop from 131,700 miners in 1948 to just 20,100 in 2006, a five-fold decrease even after accounting for population decline (Bell and York 2010). This decline continued with coal mine employment falling from nearly 14,500 workers in early 2018 to just over 11,000 in late 2020 (Witt and Fletcher 2005; Witt and Leguizamon 2007). Despite these challenges, there have been some improvements due to increased global coal demand and temporary boosts in the domestic steam coal market. In 2021, production averaged nearly 80 million short tons. Although mining only comprises 3% of statewide employment, it accounted for 15% of the state's GDP in 2021 (Bureau of Business and Economic Research 2022). This decline reflects national trends in the coal industry, as market dynamics shift toward alternative energy sources and automation reduces the need for labor.

2.2.5. Healthcare Sector

The healthcare sector has emerged as a crucial component of West Virginia's economy. Hospitals alone contribute nearly USD 10.5 billion annually and support approximately 46,000 jobs. The state's hospitals serve around 227,000 inpatients and over 7 million outpatients each year, underscoring the sector's significance (Young 2019). The sector has experienced substantial growth, particularly with the expansion of WVU Medicine, which added more than 550 doctors nationwide over four and a half years. This growth is reflected in the broader trend of an increasing healthcare workforce over the past two decades, driven by significant changes in health-related activities (HRSA 2022). These developments align with national trends, where healthcare continues to expand due to an aging population and increasing demand for services.

2.2.6. Education Sector

West Virginia's education workforce shows a slight decline from 2001 to 2020, though it temporarily increased between 2010 and 2012 before stabilizing. In 2020, the state employed 283,044 teachers, achieving a favorable student-to-teacher ratio of 1:14 compared to the national average of 1:16. Per-pupil spending averaged USD 12,697, and the graduation rate improved significantly to 91% in the 2018–2019 school year, up from 81.4% in 2012–2013 (U.S. Census Bureau 2022; National Center for Education Statistics 2022). The public high school event dropout rate in West Virginia improved from 3.4% in 2010–2011 to 2.7% in 2011–2012, compared to a stable national rate of 3.3% during these years. However, college enrollment among high school graduates fell from 56.3% in 2011 to 48.3% in 2021 (WVHEPC (West Virginia Higher Education Policy Commission) 2023).

West Virginia's higher education sector has shown growth in recent years, with a 7% increase in degrees conferred from 2017 to 2021, totaling 32,051 degrees (WVHEPC (West Virginia Higher Education Policy Commission) 2023). The state has 36 degree-granting institutions, including 14 private colleges with about 50,000 undergraduate students, where 17,610 degrees were awarded in 2021, largely through online programs. Public colleges, comprising 13 institutions, conferred 14,116 degrees with around 44,500 students enrolled. Additionally, nine community colleges enrolled 9136 students and awarded 2144 associate degrees in 2021.

To advance its education, economy, and workforce, West Virginia should leverage its strengths in AI, machine learning, big data, and supercomputing. With 42 colleges and universities, state leaders are crucial in managing educational resources and tackling challenges like budget cuts and outmigration (Cart 2016; Williams 2012).

2.2.7. Government Sector

The government sector in West Virginia has seen a notable decline in workforce numbers, particularly since 2019. However, the federal government remains a crucial source of employment in the state, with agencies such as the FBI, US Treasury, and National Park Service expanding their staffing levels (Bureau of Business and Economic Research 2022). The long-term impact of the state's declining population on federal government decisions remains uncertain, but the sector's influence on job creation in West Virginia is undeniable. This decline reflects broader national trends, where state and local government employment has faced cuts due to budgetary pressures, while federal employment remains more stable.

2.2.8. Transportation Sector

The transportation sector in West Virginia has experienced a slight decline in workforce levels over the past two decades, with a marginal decrease particularly evident in recent years, exacerbated by the challenges posed by the COVID-19 pandemic. The state's transportation network, which includes highways, local roads, streets, bridges, airports, transit and rail, freight railroads, and ports and waterways, plays a vital role in facilitating the movement of travelers, supporting businesses, transporting freight, and driving economic growth (West Virginia Transportation by the Numbers 2021). The sector's performance aligns with national trends where transportation infrastructure remains critical but faces challenges related to funding, maintenance, and adaptation to new technologies.

West Virginia's transportation equipment sector includes a burgeoning auto parts supply chain in the Kanawha and Mid-Ohio River valleys and a diverse mix of civilian and defense aerospace production. Auto part manufacturing has been the fastest-growing segment, with a 2.5% average annual job growth since 2008. Despite past challenges, the aerospace industry in North Central West Virginia has expanded, supported by increased commercial travel efforts and new contracts at the Applied Ballistics Laboratory (ABL), which is set to grow further with upcoming Northrop Grumman hires (Bureau of Business and Economic Research 2022).

Looking ahead, emerging technologies are poised to further revolutionize West Virginia's transportation sector. The impact of these technologies will be influenced by the state's unique terrain and rural road network. To navigate these changes effectively, the West Virginia Department of Transportation (WVDOT) must proactively prepare by incorporating insights from peer states and integrating new technologies into the 2050 Long-Range Transportation Plan (West Virginia Transportation by the Numbers 2021).

2.2.9. Finance Sector

The finance sector in West Virginia has shown a declining trend of employees as in the other sectors. From 2001 to 2020, the finance sector in West Virginia experienced a decline, encompassing roles in securities, commodity contracts, financial investments, real estate, and leasing services. This reduction aligns with national trends influenced by consolidation, technological advancements, and regulatory changes, which have diminished traditional finance roles while increasing demand for fintech and data analysis skills. Currently, approximately 18,000 employees are in the state's financial sector, including banks, insurance companies, investment firms, real estate agencies, and property management services (Bureau of Business and Economic Research 2022). This represents a loss of 4000 jobs compared to the year 2000.

2.2.10. Utilities Sector

The utilities sector has exhibited a general decline over time, with a slight increase observed after 2016. The sector indicates a decrease in workforce numbers, particularly during the pandemic. Utility services in West Virginia encompass the provision and distribution of electricity, natural gas, water, and wastewater treatment, all of which are essential for supporting residential, commercial, and industrial activities across the state. While West Virginia's coal plants suggest increased utility spending and ratepayer costs, a shift toward clean energy could create an affordable and reliable energy supply for ratepayers, accompanied by additional long-term community benefits (Massie et al. 2023). This transition reflects a broader national and global trend toward sustainable energy practices, as environmental concerns and economic incentives drive the shift away from fossil fuels.

2.2.11. Service Sector

West Virginia's service industry is diverse, encompassing sectors such as health and education, biometrics and government, hospitality, media and telecommunications, printing, retail, tourism, and banking. The community, personal, and business service sectors hold the largest share of the gross product within this industry, with tourism and healthcare playing pivotal roles in driving growth and creating numerous job opportunities. Employment in entertainment and accommodation services indicates a substantial decline during the onset of the COVID-19 pandemic but has rebounded significantly since spring 2021 (Bureau of Business and Economic Research 2022). This recovery is consistent with national trends in the service industry, where the pandemic caused widespread disruption, followed by a gradual but uneven recovery as restrictions eased and consumer confidence returned.

3. Data and Methods

3.1. Data

The primary source of data for this study was the Bureau of Labor Statistics (BLS). Employment changes in West Virginia over a 20-year period, from 2000 to 2020, were carefully examined to gain insights into workforce trends within the state. In addition to the BLS data, census data and other relevant information pertaining to West Virginia were incorporated to provide a comprehensive view of the economic and demographic factors influencing employment patterns.

To conduct the analysis, a detailed panel dataset spanning the last two decades was carefully compiled. This dataset allowed for a thorough examination of employment trends over time, enabling a deeper understanding of the shifts and dynamics within West Virginia's labor market. By integrating various sources of data, this study aimed to present a robust and nuanced analysis of the employment landscape in the region. To effectively achieve its main objectives, this study utilized a combination of general descriptive analysis, shift-share analysis, location quotient analysis, and Boudeville's classification following the shift-share analysis.

3.2. Shift-Share Analysis

The shift-share analysis technique, developed by Daniel Creamer in the 1940s and summarized by Dunn in 1960 (Shi and Yang 2008), is designed to evaluate changes in economic activity across different regions. This method is widely used for analyzing regional employment growth by breaking down total growth into three components: the National Growth Effect (NGE), the Industry Mix Effect (IME), and the competitive effect (CE) (Barff and Knight 1988; Knudsen 2000; Wilson and Chern 2005; Herath et al. 2010, 2013; Herath Bandara 2024).

Shift-share analysis can be conducted using various methods, each offering distinct insights into regional economic growth. These methods include standard shift-share analysis, dynamic shift-share analysis, and spatial shift-share analysis. Each method differs in terms of its data requirements and the depth of analysis it provides.

Standard shift-share analysis is the most straightforward and commonly used approach, breaking down employment changes into three components: national growth, industry mix, and regional competitive effects. It requires only basic employment data at national and regional levels, making it ideal for situations where data availability is limited.

Dynamic shift-share analysis introduces a temporal dimension, focusing on how regional competitiveness and industry performance evolve over time. While this method offers more in-depth insights, it requires complex time-series data, making it more challenging to implement, especially in regions lacking comprehensive historical data.

Spatial shift-share analysis considers the influence of neighboring regions on a region's economic performance. This method demands detailed data on both the target region and its surrounding areas, significantly increasing data complexity. Its application is often constrained by the unavailability of spatially detailed datasets.

In this study, the standard shift-share analysis method is employed due to its clear and straightforward breakdown of employment changes into national growth, industry mix, and regional competitive effects. Limited data availability for the study period of 20 years made it impractical to conduct dynamic or spatial analyses. On the other hand, the focus of this study was on evaluating broad employment trends and sectoral shifts, which the standard method captures effectively. Its simplicity ensures that the findings are easily interpretable and actionable for policymakers, highlighting competitive industries and offering valuable insights for developing targeted economic strategies.

The shift-share analysis compares regional employment growth with national trends, providing insights into whether changes are driven by broader national trends, specific industry dynamics, or regional competitive advantages. By calculating these effects, shift-share analysis helps determine the actual change in regional employment and sheds light on the underlying factors influencing economic performance (Richardson 1978).

Following the notation of Richardson (1978), the three growth effects for a specific region and industrial sector are expressed as follows:

$$\text{National growth effect for sector } i \text{ in region } r = E_{ir} \times G_n.$$

$$\text{Industrial mix effect for sector } i \text{ in region } r = E_{ir} \times (G_{in} - G_n).$$

$$\text{Competitive effect for sector } i \text{ in region } r = E_{ir} \times (G_{ir} - G_{in}).$$

where

E_{ir} = employment in sector i in region r at the beginning of the time period.
G_n = growth rate for total employment for the nation over the time period.
G_{in} = growth rate in sector i for the nation for the time period.
G_{ir} = growth rate in sector i in region r for the time period.

In this specific investigation, the utilization of shift-share analysis is employed to evaluate employment growth in five significant regions of West Virginia: Mid-Ohio Valley, Metro Valley, New River/Greenbrier Valley, Potomac Highlands, and Mountain Lakes. Figure 1 illustrates the regional sectors of West Virginia, while Table 1 lists the counties within each sector out of the state's 55 counties. This assessment is made in relation to the overall employment growth within the state, with state employment growth acting as a benchmark akin to national growth. The primary focus lies in comparing the average regional employment growth to that of the state, highlighting the influence of the state growth effect (SGE), industrial mix effect (IME), and competitive effect (CE). The cumulative impact of these factors reveals the actual change in total employment within each region during the specified study period.

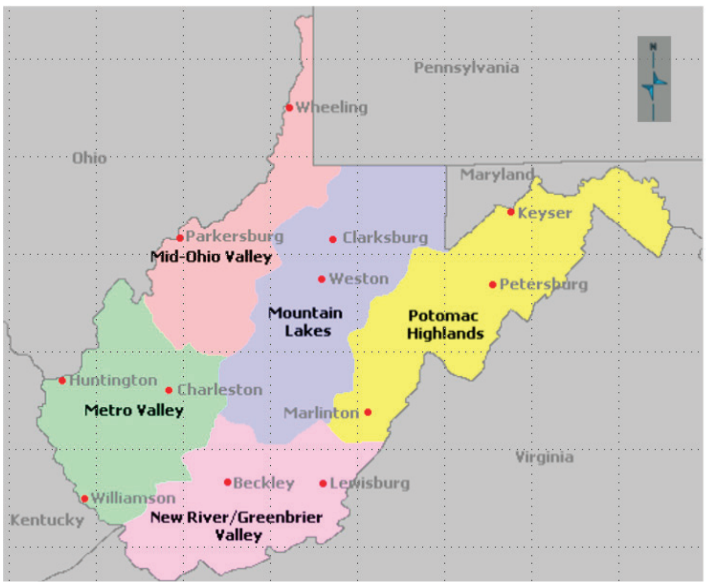

Figure 1. Regional map of West Virginia. Source: Virginia-map.com (2022).

Table 1. Regional sectors and counties, West Virginia.

Regional Sectors	Counties
Metro Valley	Boone, Cabell, Kanawha, Lincoln, Logan, Mason, Mingo, Putnam, Wayne
Mid-Ohio Valley	Brooke, Calhoun, Hancock, Jackson, Marshall, Ohio, Pleasants Ritchie, Roane, Tyler, Wetzel, Wirt, Wood
New River and Greenbrier Valley	Fayette, Greenbrier, Mercer, Monroe, McDowell, Raleigh, Summers, Wyoming
Mountain and Lakes	Barbour, Braxton, Clay, Doddridge, Gilmer, Harrison, Lewis, Marion, Monongalia, Nicholas, Preston, Taylor, Upshur, Webster
Potomac Highlands	Berkeley, Grant, Hampshire Hardy, Jefferson, Mineral, Morgan, Pendleton, Pocahontas, Randolph, Tucker

3.3. Location Quotient Analysis

The industry location quotient (*LQ*) is a tool used to measure the concentration of an industry within a specific region compared to a broader geographical area, such as a state or the nation (Richardson 1973). It provides insights into the economic structure of a region by identifying key industries, pinpointing export-oriented sectors, recognizing emerging industries, and highlighting sectors that may be detrimental to the region's economic stability.

The formula for calculating an industry location quotient is:

$$LQ_i = \frac{(E_iS/ES)}{(E_iR/ER)}$$

where

- LQ_i represents the location quotient for sector i within the subregion.
- E_iS denotes the number of employees in sector i within the subregion.
- ES indicates the total number of employees within the subregion.
- E_iR stands for the number of employees in sector i within the region.
- ER stands for the number of employees within the region.

The location quotient (*LQ*) is a tool used to assess the concentration of employment in a specific industry within a subregion relative to a larger reference area. An *LQ* of 1 signifies that the industry's employment share in the subregion is proportional to its share in the reference area, indicating no significant deviation. When the *LQ* exceeds 1, it suggests a higher concentration of employment in the subregion, which may indicate a specialized or export-oriented sector. Conversely, an *LQ* below 1 implies that the industry is less concentrated in the subregion compared to the reference area, reflecting a lower relative presence. By analyzing *LQ*s, policymakers and economists can better understand which industries are driving regional economic performance, which sectors are emerging, and which might be lagging, thereby informing targeted economic strategies and development plans.

4. Results and Discussion

4.1. Descriptive Analysis

In 2001, the Metro Valley region led with over 203,600 jobs and remained the highest in 2020 with approximately 166,000 positions. The Mountain and Lakes region followed with more than 122,500 jobs in 2001, experiencing only a slight decline to a similar level in 2020. Ohio Valley shows a significant drop from 113,000 jobs in 2001 to around 93,000 by 2020. The New River and Greenbrier region recorded over 83,000 jobs in 2001 and decreased to about 71,000 by 2020. The Potomac Highlands region, which had the lowest employment figure in 2001 with over 71,500 jobs, indicates a slight decline, maintaining roughly 71,000 jobs by 2020. Overall, West Virginia experienced a decline of about 70,000 jobs from 2001 to 2020, reflecting a reduction in total employment across all regions during this period.

The descriptive analysis of the Metro Valley region from 2001 to 2020 reveals significant shifts in the employment landscape. Figure 2 shows the employment changes across various sectors during this period, highlighting that some sectors experienced growth, while others saw declines. For instance, the healthcare sector has grown substantially, reflecting a trend toward service-oriented jobs. In contrast, traditional industries such as manufacturing, mining, construction, and retail trade have experienced declines. Meanwhile, sectors like agriculture and entertainment have remained relatively stable, with only minor fluctuations in employment. Overall, the region's economy has increasingly shifted towards healthcare and hospitality, marking a departure from the prominence of traditional industries in 2001.

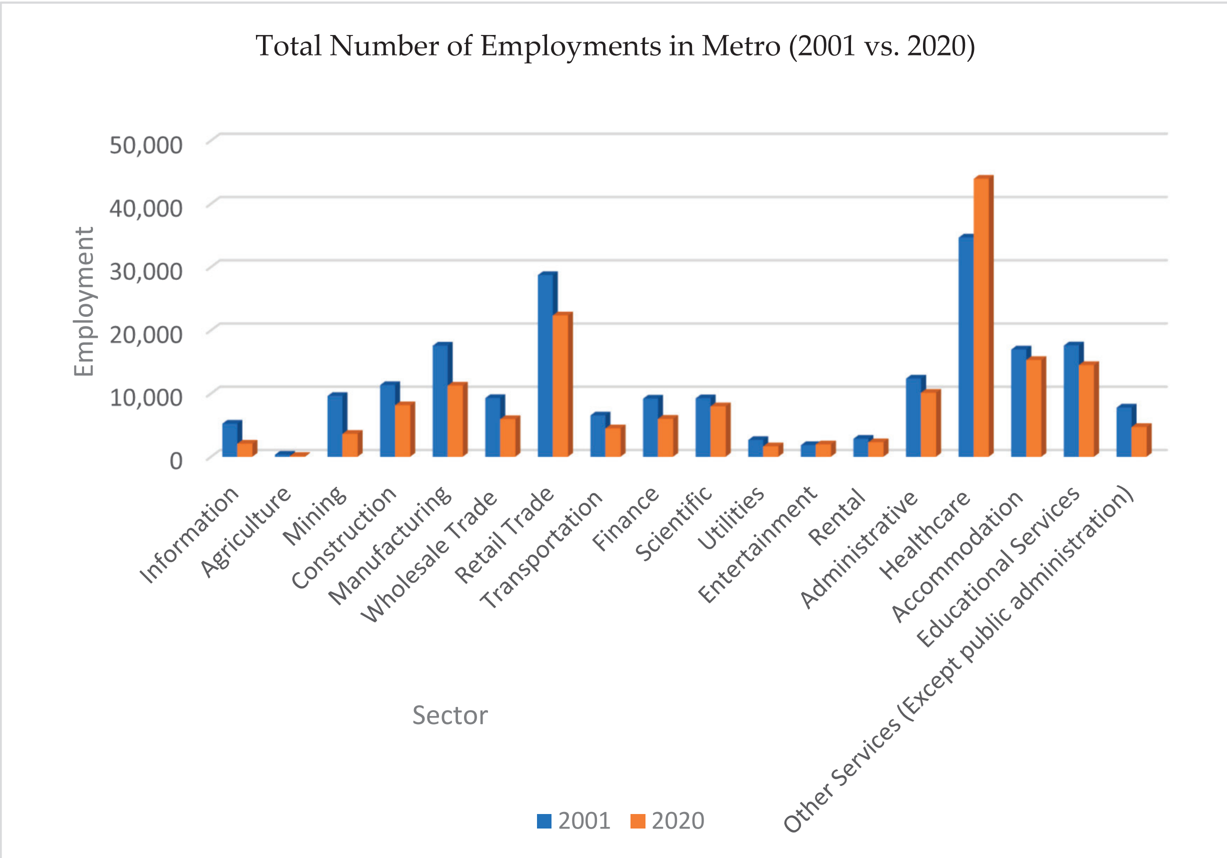

Figure 2. Sectoral employment change in the Metro Valley Region, 2001 and 2020.

Employment trends in the Mid-Ohio Valley region from 2001 to 2020 reveal significant changes, including a loss of approximately 20,000 jobs. Figure 3 highlights the employment differences across various sectors during this period. The healthcare and accommodation sectors experienced substantial growth, reflecting their expanding roles, while manufacturing saw a notable decline. The wholesale trade sector also decreased, although retail trade remained stable. Construction and mining maintained consistent employment levels, underscoring their ongoing importance. Overall, the region's workforce has shifted toward service industries, particularly healthcare and hospitality, while traditional sectors like manufacturing and wholesale trade have contracted.

Employment trends in the New River and Greenbrier Valley region from 2001 to 2020 reveal significant shifts across industries, with a total job loss of approximately 12,000 during this period. Figure 4 illustrates how employment numbers in each sector changed over these two decades. The healthcare sector experienced substantial growth, highlighting its increasing importance, while administrative roles also expanded. In contrast, the manufacturing and information sectors saw declines, reflecting a broader industrial downturn. The construction sector faced a sharp decrease, and although retail trade experienced a reduction, it remained a key industry. Accommodation and food services also declined due to reduced demand. Overall, healthcare and retail have emerged as the primary employment drivers in the region.

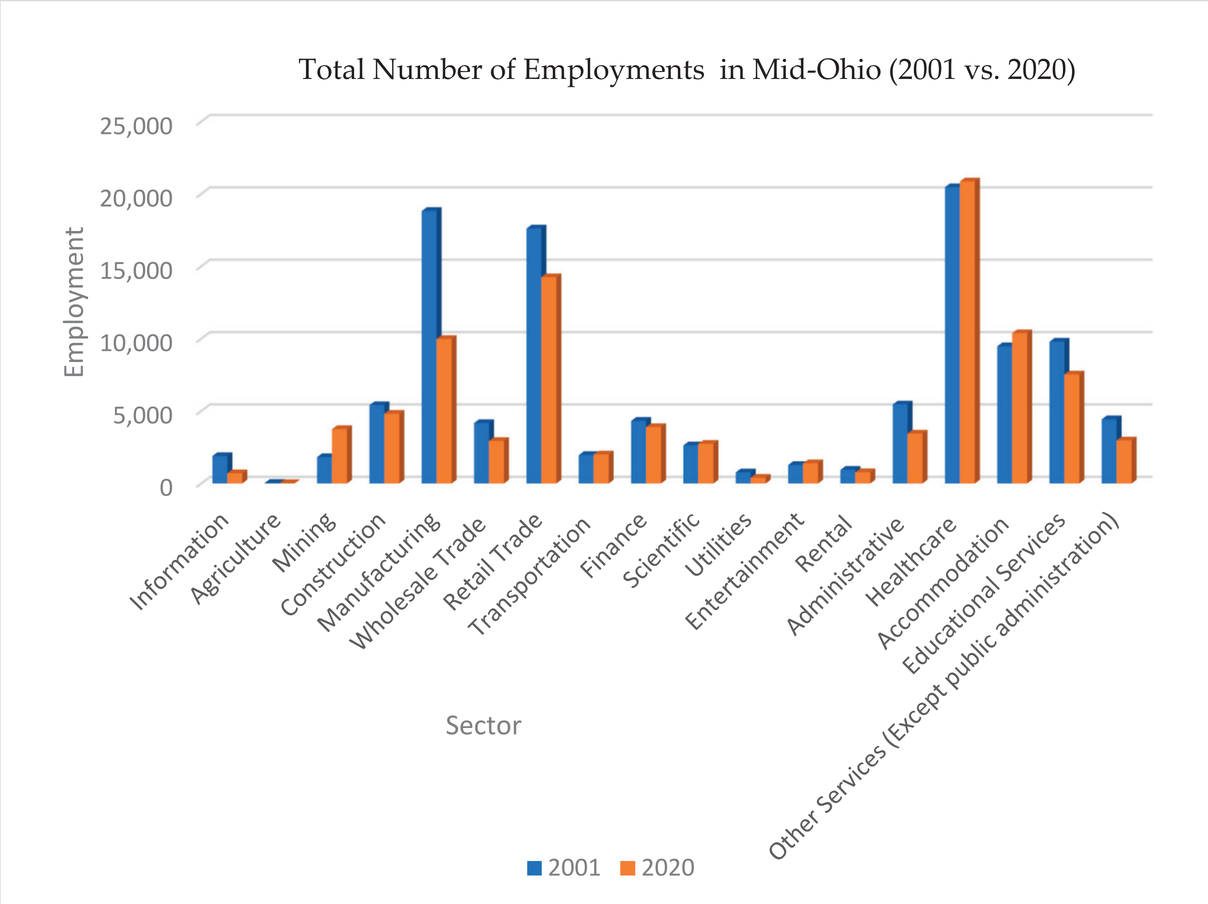

Figure 3. Sectoral employment change in the Mid-Ohio Valley Region, 2001 and 2020.

In the Mountain and Lakes Valley region of West Virginia, employment trends from 2001 to 2020 reveal significant shifts across industries, while the total number of jobs remained relatively stable over the period. Figure 5 highlights the changes in sectoral employment between 2001 and 2020. The healthcare sector experienced substantial growth, along with the accommodation, entertainment, and construction sectors, driven by rising demand. In contrast, the manufacturing and information sectors saw declines, reflecting broader industrial reductions. Retail trade remained steady, with only minor fluctuations. Overall, the healthcare, retail, education, and accommodation sectors emerged as key contributors to local job growth.

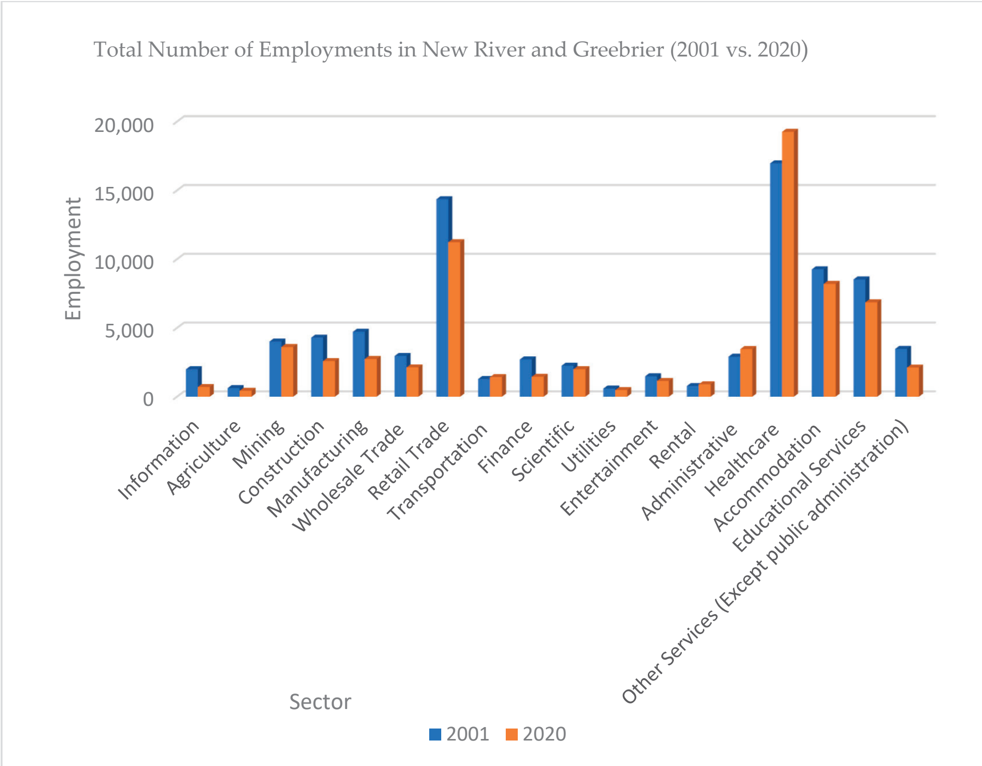

Figure 4. Sectoral employment change in the New River and Greenbrier Valley region, 2001 and 2020.

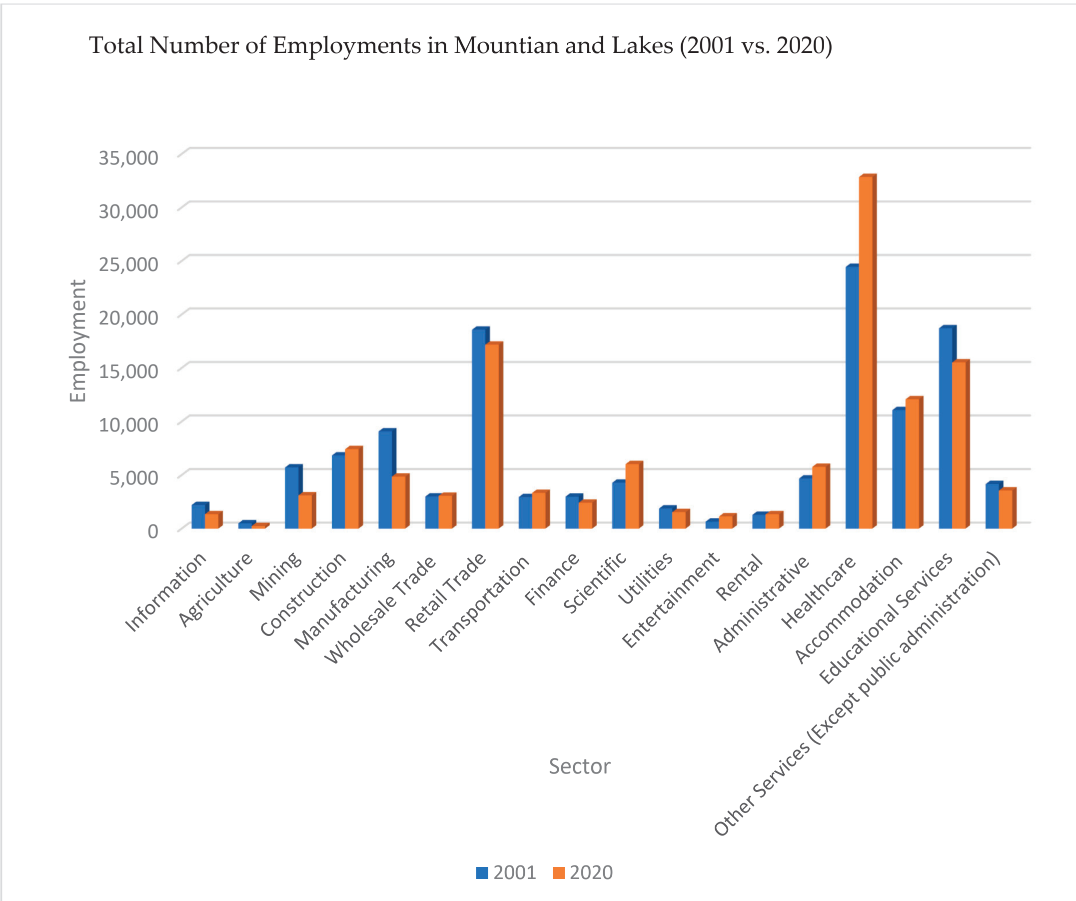

Figure 5. Sectoral employment change in the Mountain and Lakes Valley Region, 2001 and 2020.

In the Potomac Highlands region of West Virginia, which had the lowest employment numbers in 2001, there was no significant decline by 2020. Figure 6 illustrates the changes in employment across sectors between 2001 and 2020. The healthcare sector shows considerable growth, along with increases in accommodation, educational services, and retail trade. In contrast, the manufacturing, information, and construction sectors experienced declines, reflecting broader industrial trends. Retail trade remained stable with a slight increase. Overall, the region is shifting towards service-oriented sectors, particularly healthcare, while traditional industries like manufacturing have diminished.

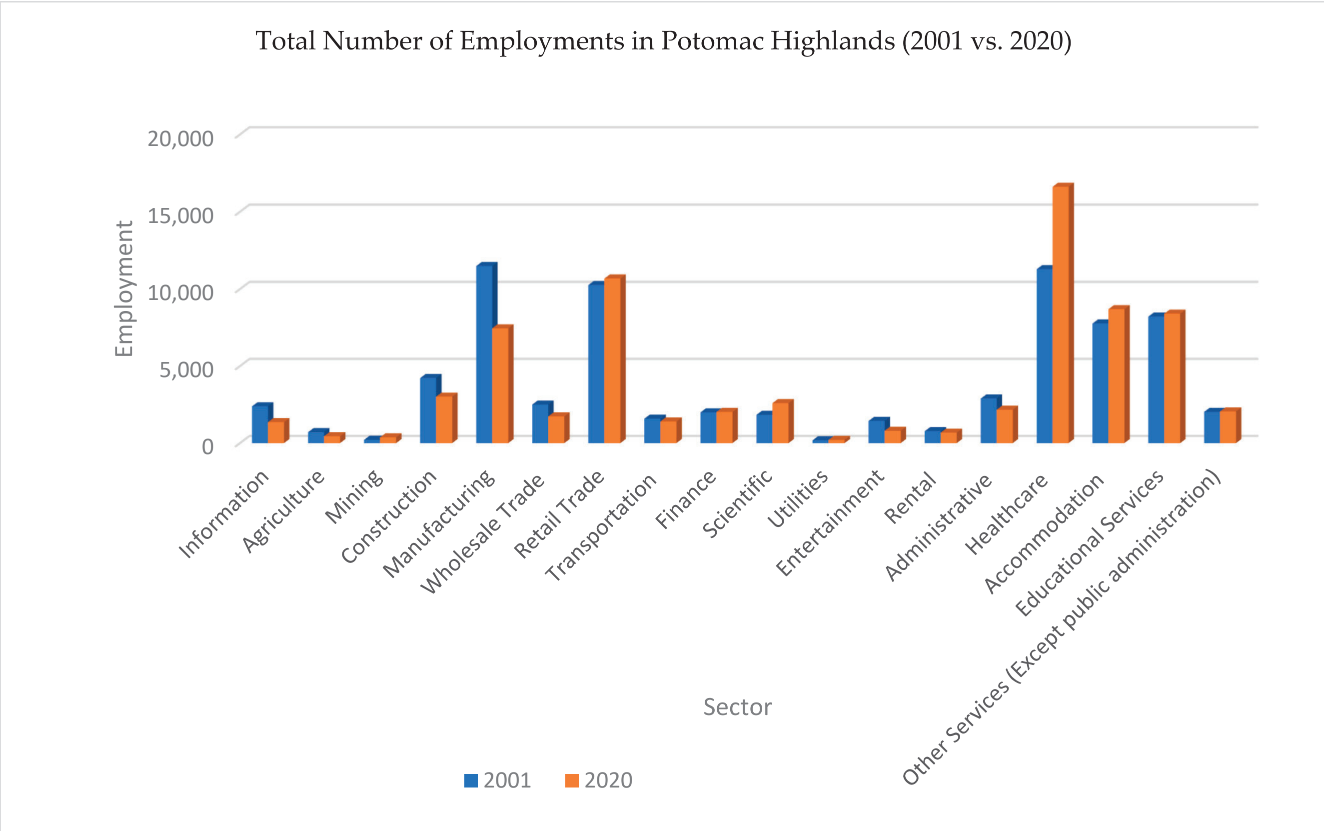

Figure 6. Sectoral employment change in the Potomac Highlands Region, 2001 and 2020.

4.2. Shift-Share Analysis

This analysis employs a methodology to assess the growth of five key regions in West Virginia: Mid-Ohio Valley, Metro Valley, New River/Greenbrier Valley, Potomac Highlands, and Mountain Lakes, in comparison to the overall employment growth in the state. State employment growth serves as a benchmark like national growth. The primary focus is on contrasting regional employment growth averages with state employment growth, emphasizing the impact of the state growth effect (SGE), industrial mix effect (IME), and competitive effect (CE). The cumulative influence of these factors reveals the actual change in total employment within each region over the specified study period.

In the shift-share analysis for the Mid-Ohio Valley region, the results present a mixed picture of employment trends, highlighting growth in some sectors due to favorable conditions while others face declines due to broader economic challenges.

According to the shift-share analysis of key sectors or industries shown in Table 2, the healthcare sector experienced a net gain of 394 jobs. This growth was primarily driven by a positive competitive effect (CE). However, negative state growth and industrial mix effects (IME) suggest that despite this growth, the sector lagged behind state averages and faced competitive challenges. The accommodation sector also showed notable growth, with an increase of 905 jobs. The positive IME and competitive effect indicate that this sector not only outperformed its competitors but also benefited from advantageous changes in industry composition. Despite a negative state growth effect, which suggests that overall state trends were not favorable for this sector, the accommodation industry demonstrated resilience and competitiveness in the regional market.

Table 2. Employment growth in Mid-Ohio Valley in West Virginia: 2001–2020.

Sectors/Industries	SGE	IME	CE	Actual Growth
Total Industries	−13,096.29	0.00	−5401.71	−18,498.00
Information	−223.46	−822.88	−149.66	−1196.00
Agriculture	−4.82	−13.34	−22.84	−41.00
Mining	−214.64	−375.73	2521.37	1931.00
Construction	−636.16	−395.21	439.37	−592.00
Manufacturing	−2214.14	−5538.63	−1088.24	−8841.00
Wholesale Trade	−491.38	−675.95	−69.67	−1237.00
Retail Trade	−2071.47	−653.70	−636.83	−3362.00
Transportation	−230.87	−0.43	267.30	36.00
Finance	−508.78	−600.87	674.65	−435.00
Scientific	−310.26	448.98	−37.72	101.00
Utilities	−90.91	−139.04	−146.05	−376.00
Entertainment	−150.42	101.33	166.10	117.00
Rental	−111.14	18.00	−74.86	−168.00
Administrative	−641.80	−1.73	−1369.47	−2013.00
Healthcare	−2407.61	7288.51	−4486.90	394.00
Accommodation	−1114.71	1136.09	883.62	905.00
Educational Services	−1152.11	−410.13	−696.75	−2259.00
Other Services (except public admin.)	−521.60	−789.95	−150.45	−1462.00

In contrast, the mining sector shows an increase of 1931 jobs, mainly due to a favorable industrial mix effect (IME). Despite this growth, negative state growth and competitive effects reflect slower growth compared to state trends and competitive challenges. Conversely, the manufacturing sector exhibits the largest decline, losing 8841 jobs due to negative effects in all areas: state trends (SGE), industrial mix (IME), and competitive performance (CE). Educational services also declined by 2259 jobs, with negative competitive effects and unfavorable IME and SGE contributing to the reduction. The agriculture sector experienced a slight decrease of 41 jobs, reflecting broader struggles to keep pace with economic growth and competitiveness.

Examining the shift-share analysis of key sectors in the Metro Valley region from 2001 to 2020, as shown in Table 3, the healthcare sector stands out with significant growth, adding 9291 jobs. The positive industrial mix effect (IME) indicates that the sector benefited from favorable changes in its composition relative to state trends. Despite the negative state growth effect (SGE), which suggests that broader state trends were not favorable, the positive competitive effect (CE) demonstrates that the healthcare sector outperformed its competitors, reflecting strong regional demand and growth in healthcare services. The entertainment sector showed modest growth with an addition of 129 jobs, driven by a strong competitive effect (CE) and positive changes in the industry's composition, despite less favorable state trends (SGE).

In contrast, the manufacturing sector experienced a significant decline, losing 6308 jobs, due to negative effects across all components—state trends, industry composition, and competitive performance—highlighting broader industry challenges. Similarly, the retail trade sector showed a notable decline, losing 6374 jobs, as it struggled with unfavorable trends and increased competition. The educational services sector also faced significant reductions, losing 3097 jobs due to poor competitive performance and declining industry conditions, potentially reflecting issues like funding and enrollment challenges.

Table 3. Employment growth in Metro Valley in West Virginia: 2001–2020.

Sectors/Industries	SGE	IME	CE	Actual Growth
Total Industries	−23,953.63	0.00	−13,381.37	−37,335.00
Information	−615.22	−2265.51	−294.27	−3175.00
Agriculture	−37.87	−104.73	−60.40	−203.00
Mining	−1130.12	−1978.32	−2881.56	−5990.00
Construction	−1333.23	−828.28	−1041.49	−3203.00
Manufacturing	−2064.54	−5164.40	920.94	−6308.00
Wholesale Trade	−1091.43	−1501.40	−744.17	−3337.00
Retail Trade	−3377.78	−1065.93	−1930.30	−6374.00
Transportation	−769.06	−1.42	−1292.52	−2063.00
Finance	−1080.72	−1276.33	−841.95	−3199.00
Scientific	−1086.49	1572.26	−1755.78	−1270.00
Utilities	−311.55	−476.47	−214.98	−1003.00
Entertainment	−215.82	145.38	199.44	129.00
Rental	−334.37	54.14	−276.78	−557.00
Administrative	−1453.78	−3.92	−790.30	−2248.00
Healthcare	−4075.44	12,337.52	1028.92	9291.00
Accommodation	−1994.56	2032.81	−1700.25	−1662.00
Educational Services	−2068.53	−736.36	−292.10	−3097.00
Other Services (except public admin.)	−913.13	−1382.90	−769.98	−3066.00

Table 4 highlights employment growth in the New River/Greenbrier Valley region over the past two decades, with notable gains in healthcare, rental, transportation, and administrative services, and minimal losses in agriculture and utilities.

Table 4. Employment growth in New River/Greenbrier Valley in West Virginia: 2001–2020.

Sectors/Industries	SGE	IME	CE	Actual Growth
Total Industries	−9784.49	0.00	−2726.51	−12,511.00
Information	−234.52	−863.59	−194.90	−1293.00
Agriculture	−73.98	−204.59	77.56	−201.00
Mining	−471.38	−825.17	898.56	−398.00
Construction	−505.02	−313.75	−888.24	−1707.00
Manufacturing	−555.12	−1388.63	−39.25	−1983.00
Wholesale Trade	−348.36	−479.22	−10.42	−838.00
Retail Trade	−1688.42	−532.82	−907.77	−3129.00
Transportation	−151.25	−0.28	290.53	139.00
Finance	−318.61	−376.27	−569.12	−1264.00
Scientific	−265.09	383.62	−378.53	−260.00
Utilities	−69.51	−106.30	62.81	−113.00
Entertainment	−174.30	117.41	−283.11	−340.00
Rental	−91.27	14.78	197.49	121.00
Administrative	−342.01	−0.92	897.93	555.00
Healthcare	−1995.38	6040.58	−1756.20	2289.00
Accommodation	−1089.07	1109.96	−1083.89	−1063.00
Educational Services	−1002.63	−356.92	−306.45	−1666.00
Other Services (except public admin.)	−408.58	−618.78	−332.64	−1360.00

The healthcare sector added 2289 jobs, driven by a favorable industrial mix effect (IME), despite unfavorable state trends (SGE) and comparative effect (CE). Similarly, administrative services grew by 555 jobs, benefiting from positive competitive and industry composition effects. The rental sector also highlights modest growth, adding 121 jobs, with its performance bolstered by strong CE and IME, despite negative state trends.

Conversely, the retail trade sector lost 3129 jobs, facing declines across all components—state trends, industry composition, and competitiveness—highlighting challenges like changing consumer behavior. The educational services sector lost 1666 jobs, hindered by weak competitive performance and unfavorable industry and state trends. Manufacturing also faced significant losses, with 1983 jobs lost due to negative impacts across all components, reflecting broader industry challenges and reduced regional competitiveness. The agriculture sector in the New River/Greenbrier Valley region indicates a modest decline of 201 jobs from 2001 to 2020. Negative state growth and industrial mix effects indicate unfavorable state trends and sector composition. However, a positive competitive effect suggests that the sector performed relatively well compared to other regions, showing some resilience despite broader challenges.

Table 5 presents the shift-share analysis for the Potomac Highlands region from 2001 to 2020, revealing mixed employment trends across various sectors. Growth was observed in healthcare, scientific services, retail trade, education, and accommodation, while sectors such as manufacturing, construction, entertainment, and administrative services experienced significant declines.

Table 5. Employment growth in Potomac Highlands in West Virginia: 2001–2020.

Sectors/Industries	SGE	IME	CE	Actual Growth
Total Industries	−8447.03	0.00	7345.03	−1102.00
Information	−280.97	−1034.66	285.63	−1030.00
Agriculture	−83.62	−231.26	51.88	−263.00
Mining	−25.29	−44.26	230.55	161.00
Construction	−496.90	−308.70	−403.39	−1209.00
Manufacturing	−1351.46	−3380.66	692.13	−4040.00
Wholesale Trade	−294.73	−405.44	−73.82	−774.00
Retail Trade	−1207.15	−380.94	2007.10	419.00
Transportation	−187.24	−0.35	0.58	−187.00
Finance	−234.63	−277.10	537.73	26.00
Scientific	−216.40	313.16	662.24	759.00
Utilities	−21.88	−33.46	79.33	24.00
Entertainment	−169.95	114.48	−587.53	−643.00
Rental	−91.27	14.78	−20.51	−97.00
Administrative	−340.25	−0.92	−383.84	−725.00
Healthcare	−1327.47	4018.63	2641.84	5333.00
Accommodation	−913.36	930.88	911.48	929.00
Educational Services	−966.05	−343.90	1498.95	189.00
Other Services (except public admin.)	−238.40	−361.04	625.44	26.00

The healthcare sector led the region's growth, adding 5333 jobs. This growth was primarily driven by a strong industrial mix effect (IME) and competitive effect (CE), suggesting that the sector benefited from favorable changes in its industry composition compared to state trends. Despite a negative state growth effect (SGE), the healthcare sector's positive competitive effect (CE) indicates it outperformed its competitors, reflecting robust regional demand and expansion in healthcare services. The scientific sector also experienced growth, adding 759 jobs. This increase was largely supported by a favorable IME, which highlights the sector's benefit from advantageous changes in industry composition. The positive CE further underscores the sector's strong performance relative to its competitors, despite broader state trends not being supportive. The accommodation sector added 929 jobs, driven by a positive IME and strong regional competitiveness. Despite unfavorable state trends, the sector leveraged its advantages to outperform competitors.

On the other hand, the manufacturing sector experienced a significant decline, losing 4040 jobs. This downturn was driven by negative effects across all components: an unfavorable SGE, a declining IME, and a poor CE, highlighting the sector's struggles with competitiveness and broader industry challenges. Similarly, the entertainment sector experienced a decline of 643 jobs, primarily due to a negative CE, indicating underperformance compared to competitors. Despite some favorable changes in the sector's composition, as reflected by a positive IME, the overall decline was exacerbated by unfavorable state trends. Administrative services also faced a reduction of 725 jobs. The sector was negatively impacted across all components, with the SGE, IME, and CE all reflecting broader regional challenges and difficulties in maintaining competitiveness.

Table 6 presents the shift-share analysis results for the Mountain Lakes region from 2001 to 2020, showing significant employment growth in the healthcare, scientific, administrative, and accommodation sectors. Conversely, the mining, manufacturing, and educational services sectors experienced declines.

Table 6. Employment growth in Mountain Lakes in West Virginia: 2001–2020.

Sectors/Industries	SGE	IME	CE	Actual Growth
Total Industries	−14,463.28	0.00	14,217.28	−246.00
Information	−259.10	−954.10	353.20	−860.00
Agriculture	−58.22	−161.00	−35.78	−255.00
Mining	−672.26	−1176.82	−768.92	−2618.00
Construction	−802.93	−498.82	1893.75	592.00
Manufacturing	−1067.67	−2670.76	−485.58	−4224.00
Wholesale Trade	−352.36	−484.72	898.08	61.00
Retail Trade	−2185.20	−689.59	1467.79	−1407.00
Transportation	−346.48	−0.64	734.12	387.00
Finance	−351.07	−414.61	198.68	−567.00
Scientific	−503.73	728.95	1509.78	1735.00
Utilities	−220.17	−336.72	218.88	−338.00
Entertainment	−76.92	51.81	505.11	480.00
Rental	−151.13	24.47	174.66	48.00
Administrative	−550.18	−1.48	1645.67	1094.00
Healthcare	−2875.11	8703.77	2572.34	8401.00
Accommodation	−1301.60	1326.56	989.04	1014.00
Educational Services	−2200.14	−783.21	−203.65	−3187.00
Other Services (except public admin.)	−489.02	−740.61	627.63	−602.00

The healthcare sector indicates significant growth, adding 8401 jobs. This increase was largely driven by a strong industrial mix effect (IME), indicating favorable changes in the sector's composition despite an unfavorable state growth effect (SGE). The positive competitive effect (CE) further underscores the sector's outperformance relative to competitors, reflecting a strong regional demand. The scientific sector added 1735 jobs, supported by a favorable IME and positive CE, demonstrating strong performance despite a negative SGE. Similarly, administrative services grew by 1094 jobs, driven by positive CE and IME, showing resilience and competitiveness despite unfavorable state trends.

Conversely, the mining sector experienced a decline of 2618 jobs, influenced by negative effects across all components: an unfavorable SGE, a declining IME, and a poor CE. This downturn highlights broader challenges and reduced competitiveness in the mining industry. The manufacturing sector also faced a significant decline, losing 4224 jobs. Negative effects across the SGE, IME, and CE reflect broader industry challenges and diminished regional competitiveness. The educational services sector experienced a decline of 3187 jobs, with negative effects across all components, including an unfavorable SGE, a declining IME, and poor performance relative to the competitors. This decline suggests challenges such as funding issues and declining enrollment amid broader state trends.

4.3. Location Quotient Analysis

Location quotients (*LQ*s) are ratios used to compare employment distribution across different industries within a specific area relative to a reference area, typically the overall industry total (Richardson 1973). According to the Bureau of Labor Statistics, an *LQ* of 1 indicates that the industry's share of local employment is proportional to its share in the reference area. An *LQ* greater than 1 signifies that the industry has a higher proportion of local employment compared to the reference area.

Table 7 presents the *LQ*s for all regions of West Virginia for the year 2020. The first column of the table lists each sector or industry, while the remaining columns show the regions. The table illustrates changes in employment numbers over the 20-year period across all regions, highlighting the critical importance of certain industries to specific regions of West Virginia in terms of employment. This underscores the need to understand and prioritize key industries within the regions. Additionally, *LQ* analysis identifies emerging industries and emphasizes the need for focused development efforts. This insight helps policymakers and stakeholders make informed decisions about resource allocation and economic development strategies.

Table 7. Location quotient analysis for all regions in West Virginia, 2020.

	Mid-Ohio Valley	Metro Valley	New River/Greenbrier	Potomac Highlands	Mountain Lakes
Total Industries	**1**	**1**	**1**	**1**	**1**
Information	0.6438	1.0497	0.8422	1.6319	0.9292
Agriculture	0	0.2886	2.4434	2.5563	0.7891
Mining	1.4640	0.7875	1.8487	0.1924	0.9137
Construction	1.0454	0.9853	0.7375	0.8594	1.2182
Manufacturing	1.5515	0.9755	0.5587	1.5202	0.5706
Wholesale Tde	1.0493	1.1837	0.9956	0.8114	0.8252
Retail Trade	1.0614	0.9290	1.0984	1.0446	0.9676
Transportation	0.8915	1.1144	0.8349	0.8227	1.1246
Finance	1.3911	1.1955	0.6787	0.9487	0.6540
Scientific	0.7242	1.1760	0.6926	0.90227	1.2038
Utilities	0.5246	1.2143	0.8298	0.3644	1.5338
Entertainment	1.2222	0.9599	1.3134	0.9219	0.7511
Rental	0.7333	1.2044	1.1121	0.8414	0.9518
Administrative	0.7777	1.2748	1.0273	0.6428	0.9861
Healthcare	0.8807	1.0355	1.0677	0.9211	1.0490
Accommodation	1.0708	0.8807	1.1105	1.1774	0.9426
Edu. Services	0.8044	0.8634	0.9617	1.1775	1.2532
Other Services	1.0885	0.9602	1.0168	0.9869	0.9850

4.3.1. Mid-Ohio Region

Table 7 presents the location quotients (LQs) for employment concentration in the Mid-Ohio Valley region, highlighting several sectors with positive LQs that exceed the state average. Among these, mining, manufacturing, and finance stand out as the key sectors with the highest LQs, indicating their significant role in the region's economy in 2020.

Notably, the mining sector, with an LQ of 1.4640, stands out for its significant job concentration, underscoring its critical role in the regional economy. This elevated LQ highlights the sector's reliance on local natural resources and active mining operations, indicating that the Mid-Ohio Valley has maintained a competitive advantage in mining. This advantage is likely due to key facilities and a skilled workforce. The positive competitive effect observed in the shift-share analysis for the region (Table 2) further underscores the importance of continued investment in mining for the region's economic stability.

Similarly, the manufacturing sector stands out with an LQ of 1.5515, indicating a strong concentration of manufacturing jobs in the Mid-Ohio Valley region. This high LQ suggests a sustained competitive advantage in manufacturing. However, the competitive effect (CE) from the shift-share analysis for the period 2000–2020 (Table 2) reveals that the region is underperforming relative to the state average. This underperformance implies that further investments in manufacturing may not yield long-term benefits for the region.

The finance sector also demonstrates a strong LQ of 1.3911, indicating a higher concentration of financial services employment compared to the state average. This is reinforced by the competitive effect in shift-share analysis, underscoring the sector's potential for driving regional economic growth in the future. Similarly, the entertainment sector reflects this trend, with both its LQ value and shift-share analysis suggesting its growing importance in the region.

4.3.2. Metro Valley Region

In the Metro Valley region, several industries displayed notable location quotient (LQ) values in 2020 (Table 7). Among these, the Wholesale Trade, Transportation, and Utilities sectors are particularly significant, reflecting the region's diverse and strategically important economic activities.

The Wholesale Trade sector, with an LQ of 1.1837, indicates a higher concentration of jobs compared to the state average, highlighting the Metro Valley region's pivotal role in distribution and trade. This advantage is likely supported by the region's strategic location and infrastructure, which bolster wholesale activities in 2020. However, the competitive effects (CE) from the shift-share analysis for the region (Table 3) suggest that this sector may not provide long-term regional benefits, as the growth may not be driven by local advantages. Comparing *LQ*s with CE helps identify whether concentrated sectors are expanding due to regional strengths (positive CE) or facing local challenges (negative CE). Similarly, the Transportation sector, with an *LQ* of 1.1144, and the Utilities sector, with an *LQ* of 1.2143, also show significant employment concentrations, yet both lack positive competitive effects in the shift-share analysis, indicating potential challenges in sustaining these sectors' growth.

However, the healthcare sector (*LQ* 1.0355), along with manufacturing (*LQ* 0.9755) and entertainment (*LQ* 0.9555), all exhibit *LQ*s close to 1 and demonstrate positive competitive effects in the shift-share analysis. This indicates that these sectors are benefiting from local advantages, suggesting that future investments in these areas could drive regional employment growth. These findings point to the Metro Valley region's strong potential in sectors like healthcare, manufacturing, and entertainment, underscoring the importance of strategic investments to capitalize on these local strengths.

4.3.3. New River/Greenbrier Valley Region

In the New River/Greenbrier Valley region, several industries exhibited notable location quotient (*LQ*) values in 2020, particularly in agriculture, mining, entertainment, rental, and administrative services (see Table 7). For example, the agriculture sector stands out with a high *LQ* of 2.4434, indicating that employment in this industry is more than twice as concentrated in this region compared to the state average. This underscores agriculture's vital role in the local economy, likely driven by the region's rural character and extensive farming activities. The positive competitive effects in the shift-share analysis (Table 4) further support this advantage. Similarly, the mining sector, with an *LQ* of 1.8487, administrative services with an *LQ* of 1.1105, and rental services with an *LQ* of 1.1101, demonstrate strong regional concentrations and positive competitive effects, highlighting the local benefits in these industries.

However, while the entertainment sector shows a notable *LQ* of 1.3234, its competitive effects are less favorable, with negative values (see Table 4). This suggests that the sector's concentration may not be driven by local advantages but rather by other factors.

4.3.4. Potomac Highlands Region

In the Potomac Highlands region, several industries exhibited notable location quotient (*LQ*) values in 2020, emphasizing their significant concentration compared to state averages (see Table 7). The agriculture sector stands out with an exceptionally high *LQ* of 2.5563, indicating that employment in agriculture is more than twice as concentrated in the Potomac Highlands as it is statewide. Despite this, the competitive effect from the shift-share analysis (Table 5) is less favorable, suggesting a lower level of local competitiveness in this sector.

The manufacturing sector also shows a strong presence with an *LQ* of 1.5202, and the shift-share analysis indicates positive competitive effects. This reflects a robust concentration of manufacturing jobs in the region, signifying that manufacturing continues to be a crucial part of the Potomac Highlands' economy, supported by local industries and production facilities.

The education sector, with an *LQ* of 1.1775, also demonstrates significant competitive effects according to the shift-share analysis. This suggests that educational services are notably more concentrated in the Potomac Highlands compared to the state average, likely due to the presence of educational institutions and support services catering to the local population.

Additionally, the rental and accommodation sectors, based on *LQ* and shift-share analysis results, could play a significant role in shaping the region's economic landscape moving forward.

4.3.5. Mountain Lakes Region

In the Mountain Lakes region, several industries exhibited notable location quotient (LQ) values in 2020, highlighting their significant concentration compared to state averages (see Table 7). Key sectors with high LQs include education, scientific services, finance, mining, healthcare, and utilities.

The scientific, healthcare, finance, and utilities sectors all show positive LQs and favorable competitive effects in the shift-share analysis (Table 6), indicating a strong regional advantage in these industries. Investing further in these sectors could yield substantial long-term benefits.

For example, the scientific sector has a robust LQ of 1.2038, reflecting a high concentration of employment in research and development or specialized technical consulting within the region. This suggests a strong presence of scientific and technical services that contribute significantly to the local economy. The utilities sector boasts an impressive LQ of 1.5338, underscoring its critical role in the region's economy. This high LQ indicates that energy production, distribution, and related services are notably more concentrated in the Mountain Lakes region compared to the state averages, likely due to the region's natural resources and infrastructure supporting local and regional energy needs.

While the education sector also stands out with an LQ of 1.2532, indicating a significant presence, the shift-share analysis suggests that it may not be as competitive in generating additional economic benefits or employment compared to other sectors.

4.4. Boudeville's Framework: Insights into West Virginia's Economic Sectors

Boudeville's (1966) classification is employed in this study to provide a structured framework for understanding the economic dynamics of different regions within West Virginia. By categorizing regions based on their economic structure, this classification aids in identifying specific challenges and opportunities for each region, particularly when analyzed alongside shift-share analysis. Boudeville's classification categorizes regions into three types: Specialized, Diversified, and Peripheral Regions.

Specialized Regions rely heavily on one or a few key industries for their economic activity, benefiting from the strong performance of these sectors while also becoming vulnerable to sector-specific shocks, such as fluctuations in commodity prices. Diversified Regions, in contrast, feature a balanced mix of industries across various sectors, including primary (like agriculture), secondary (such as manufacturing), and tertiary (like services), which enhances their resilience to economic downturns. Peripheral Regions are characterized by weaker economic structures and often face challenges like high unemployment and declining industries, necessitating targeted policy interventions to stimulate growth. When combined with shift-share analysis, Boudeville's framework provides deeper insights into how specific industries drive regional economic changes, revealing the competitive effects, structural changes, and industry mix that contribute to overall employment growth or decline in a region.

4.4.1. Mid-Ohio Valley Region

The employment growth data presented in Table 2 illustrate the findings of the shift-share analysis for the Mid-Ohio Valley region. This information can be further examined through the framework of Boudeville's (1966) classification, which offers valuable insights into the region's economic structure.

The mining sector demonstrates a significant positive competitive effect (CE) of 2521.37, indicating its dominant role in the region's economy. Despite negative trends in other sectors, mining's strong performance suggests specialization in this industry. However, such dependence on mining makes the region vulnerable to sector-specific shocks, particularly given the volatility of the mining market.

In the healthcare sector, there is notable structural growth reflected by a large industrial mix effect (IME) of 7288.51, but its negative CE of -4486.90 indicates that other factors are hindering its full growth potential. While sectors like entertainment, accommodation, and scientific services exhibit small positive competitive effects, they are insufficient to classify the region as fully diversified.

The overall decline in most sectors, including critical industries like manufacturing, retail trade, and educational services, points to characteristics of a peripheral economy. The total industries category shows a significant employment decline of −18,498 jobs, highlighting an underdeveloped or declining economic structure. Peripheral regions often require policy intervention to stimulate growth and lessen reliance on declining sectors.

4.4.2. Metro Valley Region

The employment growth data presented in Table 3 illustrates the findings of the shift-share analysis for the Metro Valley region. This information can be further examined through the framework of Boudeville's (1966) classification, which offers valuable insights into the region's economic structure.

The mining sector exhibits a negative competitive effect (CE) of −2881.56, leading to an actual job loss of −5990.00. This suggests that the region is specialized in mining, but such dependence on a declining industry has resulted in significant economic challenges.

The healthcare sector shows a positive industrial mix effect (IME) of 12,337.52 and a competitive effect (CE) of 1028.92, indicating growth potential. However, this is offset by declines in manufacturing, retail, and educational services. The mixed performance of sectors like entertainment and accommodation is insufficient to classify the region as diversified.

Overall, the Metro Valley region exhibits characteristics of a peripheral economy, with total industries experiencing an alarming employment decline of −37,335 jobs. Most sectors, especially manufacturing and retail, are in decline, highlighting the need for policy interventions to stimulate growth.

4.4.3. New River/Greenbrier Valley Region

The employment growth data in Table 4 highlight the results of the shift-share analysis conducted for the New River/Greenbrier Valley region. This analysis can be further interpreted using Boudeville's (1966) classification, which provides significant insights into the economic structure of the region.

The mining sector shows a competitive effect (CE) of 898.56, indicating its role as a key industry in the region's economy. However, despite this positive competitive effect, the overall negative growth in other sectors highlights a concerning dependence on mining. The significant loss of employment across various industries suggests that while mining may provide some stability, the region remains vulnerable to sector-specific shocks.

The healthcare sector demonstrates substantial potential with a high industrial mix effect (IME) of 6040.58, but it also has a negative CE of −1756.20. This indicates that while healthcare has growth potential, it is not currently fully realized. Other sectors, such as transportation and administrative services, show small positive competitive effects, suggesting a degree of diversity; however, these contributions are insufficient in establishing the region as a fully diversified economy.

The overall decline in most sectors, including agriculture, manufacturing, retail trade, and educational services, characterizes the New River/Greenbrier Valley as a peripheral economy. The total industries category reflects a significant employment decline of −12,511 jobs, indicating a deteriorating economic structure. This scenario underscores the need for policy interventions aimed at stimulating growth and reducing reliance on declining industries.

4.4.4. Potomac Highlands Region

The employment growth data in Table 5 highlights the results of the shift-share analysis conducted for the Potomac Highlands region. This analysis can be further interpreted using Boudeville's (1966) classification, which provides significant insights into the economic structure of the region.

The mining sector shows a competitive effect (CE) of 230.55, indicating its role in the region's economy, albeit with modest growth. However, the overall negative growth in the total industries category (−1102 jobs) suggests that while mining may be a key industry, it is not strong enough to classify the region as specialized. The presence of declining sectors raises concerns about economic stability.

The healthcare sector exhibits a notable industrial mix effect (IME) of 4018.63, coupled with a positive CE of 2641.84, indicating significant potential for growth. Additionally, sectors like scientific services, retail trade, and accommodation show small but positive competitive effects, which suggests a degree of economic diversity. However, the overall performance of many sectors is still weak, preventing the region from being classified as fully diversified.

The Potomac Highlands region displays characteristics of a peripheral region, evidenced by significant declines in critical industries such as manufacturing, retail trade, and educational services. The overall decline in employment across many sectors contributes to the region's underdeveloped economic structure. The total industries category reflects a notable employment loss of −8447.03 jobs, highlighting the need for policy interventions to stimulate growth and improve competitiveness.

4.4.5. Mountain Lakes Region

The employment growth data in Table 6 highlight the results of the shift-share analysis conducted for the Mountain Lakes region. This analysis can be further interpreted using Boudeville's (1966) classification, which provides significant insights into the economic structure of the region.

The Mountain Lakes region does not exhibit clear specialization in any single industry. Although mining has historically been a key sector, it shows a significant competitive effect (CE) of −768.92, indicating a decline in its economic contribution. The total employment loss across all industries amounts to 246 jobs, underscoring a broader economic downturn.

The healthcare sector demonstrates a significant industrial mix effect (IME) of 8703.77 and a positive CE of 2572.34, indicating strong growth potential. Additionally, sectors like scientific services and accommodation show positive competitive effects, reflecting some level of diversification within the economy. Nonetheless, the overall performance of many critical sectors remains weak, preventing classification as fully diversified.

The Mountain Lakes region largely displays characteristics of a peripheral economy, as evidenced by substantial declines across key industries such as manufacturing, retail trade, and educational services. The total industries category reflects a significant employment loss of −14,463.28 jobs, highlighting the need for policy interventions to stimulate growth and enhance economic resilience.

5. Conclusions and Policy Suggestions

The primary aim of this study is to analyze employment growth patterns across various sectors in West Virginia over the past two decades and assess their implications for long-term economic development. By employing shift-share and location quotient (LQ) analyses, this study identifies the key sectors driving regional employment and evaluates their current performance. Additionally, it applies Boudeville's framework to better understand regional economic structures, highlighting the importance of industry specialization and diversification. This approach provides guidance for policymakers in crafting strategies that address the unique challenges faced by different regions. The findings indicate a critical need for targeted policy interventions to promote economic stability and growth tailored to the diverse conditions across West Virginia.

In the Mid-Ohio Valley, location quotient (LQ) values indicate that mining, manufacturing, and finance are the most concentrated industries. However, a subsequent shift-share analysis, informed by Boudeville's classification, reveals that the region is primarily specialized in mining, with some diversification evident in healthcare and other service sectors. Despite this, a general decline across most industries, along with significant losses in manufacturing and retail, suggests that the Mid-Ohio Valley exhibits characteristics of a peripheral region.

To stabilize and promote long-term growth, economic diversification and targeted policy interventions are crucial. Specifically, in the mining sector, implementing sustainable practices and diversifying operations—such as transitioning to renewable energy or value-added processing—can enhance economic stability and reduce vulnerability to market fluctuations. This approach not only secures long-term employment opportunities but also benefits the local community.

In the Metro Valley region, location quotient (LQ) values indicate that wholesale trade, transportation, and utilities are the most concentrated sectors. However, shift-share analysis reveals that healthcare and entertainment are significant contributors to employment growth. Informed by Boudeville's classification, the analysis also shows that while the region is specialized in mining, it possesses potential in healthcare. Nonetheless, the decline across critical sectors suggests that the Metro Valley exhibits characteristics of a peripheral region.

To stabilize the economy and promote long-term growth, economic diversification strategies and targeted policy interventions are essential. Policies should prioritize enhancing infrastructure and logistics. Strategic investments in transportation networks would improve connectivity, reduce operational costs for businesses, and increase efficiency in trade and distribution.

In the New River/Greenbrier Valley region, location quotient (LQ) values indicate that agriculture and mining are the most concentrated industries. However, shift-share analysis reveals that the healthcare sector is a significant contributor to employment growth. Utilizing Boudeville's classification alongside shift-share analysis, it becomes clear that while the region specializes in mining, it faces challenges in diversification and has experienced substantial employment losses across various sectors, reflecting the characteristics of a peripheral region. To foster long-term economic stability and growth, it is crucial to implement economic diversification strategies and targeted policy interventions.

Therefore, to promote long-term economic stability and growth in the New River/Greenbrier Valley region, establishing grant programs or low-interest loans for small business development is crucial to encourage entrepreneurship and diversify the economy. Additionally, investing in tailored workforce development programs, particularly in healthcare and technology, will equip the local workforce with essential skills, enhancing employability and fostering a more resilient economy.

In the Potomac Highlands region, location quotient (LQ) values indicate that agriculture and manufacturing are the most concentrated industries. Shift-share analysis reveals that employment growth has primarily been driven by healthcare, accommodation, and scientific sectors. Boudeville's classification highlights that while the region demonstrates some strengths in healthcare, overall employment declines across various sectors suggest characteristics of a peripheral economy. The combination of specialized activities in mining and the potential for growth in healthcare underscores the urgent need for economic diversification strategies and targeted policy measures to stabilize the economy and promote long-term growth.

To enhance resilience, modernizing agricultural practices through technology and sustainability can increase productivity and create more stable job opportunities for farmers. Additionally, supporting manufacturing by investing in infrastructure and advanced technologies would foster highly skilled jobs, boosting economic output and decreasing reliance on a limited number of sectors. Lastly, improving educational opportunities is crucial for equipping the workforce with the skills needed to thrive in these evolving industries.

In the Mountain Lakes region, location quotient (LQ) values indicate that scientific services, healthcare, and utilities are the most concentrated industries. Shift-share analysis reveals that healthcare, administrative services, scientific sectors, and accommodation have significantly contributed to employment growth. According to Boudeville's classification, while the Mountain Lakes region shows promise in healthcare and some construction activities, the overall decline in critical sectors suggests it exhibits characteristics of a peripheral economy. This combination of specialized activities and potential growth in healthcare underscores the need for targeted economic diversification strategies and policy measures to stabilize the economy and foster long-term growth.

To achieve these goals, policymakers should focus on enhancing infrastructure and promoting workforce development. Investments in healthcare facilities and technological advancements can stimulate job creation and improve service delivery. Furthermore, developing training programs tailored to the needs of emerging industries will equip the local workforce with the skills necessary for future job opportunities, ultimately contributing to a more resilient and diversified economy.

This study has certain limitations. Its analysis is primarily based on location quotient (LQ) and shift-share methodologies, which may not fully reflect the dynamic nature of regional economies. Additionally, LQ and shift-share analyses do not account for external factors, such as market fluctuations or policy changes, that can significantly impact sector performance. The emphasis on specific sectors may also overlook the interconnectedness of the industries, potentially resulting in a fragmented understanding of the regional economy.

Future research could strengthen the findings by integrating additional economic indicators and qualitative assessments, providing a more comprehensive view of regional dynamics. Incorporating spatial analysis techniques and examining sector interactions could offer deeper insights into the drivers of economic growth. Moreover, conducting longitudinal studies that track changes over time would enhance our understanding of how policies and external conditions affect employment patterns, leading to more effective, tailored policy recommendations for each region.

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References

Atitwa, Sundra C. 2020. *What Are the Biggest Industries in West Virginia?* São Paulo: World Atlas. Available online: https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-west-virginia.html#:~:text=West%20Virginia%20is%20also%20a,,%20forestry,%20biometrics%20and%20tourism (accessed on 15 July 2024).

Barff, Richard A., and Prentice L. Knight, III. 1988. Dynamic Shift Share Analysis. *Growth and Change* 19: 1–10. [CrossRef]

Bartik, Timothy J. 2004. Economic Development. In *Management Policies in Local Government Finance*, 5th ed. Edited by J. Richard Aronson and Eli Schwartz. Washington, DC: International City/County Management Association, pp. 355–95.

Bell, Shannon Elizabeth, and Richard York. 2010. Community economic identity: The coal industry and ideology construction in West Virginia. *Rural Sociology* 75: 111–43. [CrossRef]

Boudeville, Jean-Rene. 1966. *Problems of Regional Economic Planning*. Edinburgh: Edinburgh University Press.

Bureau of Business and Economic Research. 2022. West Virginia Economic Outlook 2023–2027. Available online: https://business.wvu.edu/research-outreach/bureau-of-business-and-economic-research/economic-outlook-conferences-and-reports/economic-outlook-reports/west-virginia-economic-outlook-2023-2027 (accessed on 1 July 2024).

Bureau of Business and Economic Research, John Chambers College of Business and Economics, West Virginia University. 2020. *West Virginia Economic Outlook 2020–2024*. West Virginia University. Available online: https://researchrepository.wvu.edu/bureau_be/311/ (accessed on 15 July 2024).

Cart, Samantha. 2016. *Presidential Perspective: The Future of West Virginia Education*. Available online: https://wvexecutive.com/presidential-perspective-future-west-virginia-education/ (accessed on 1 July 2024).

Cieślak, Iwona, Katarzyna Pawlewicz, and Adam Pawlewicz. 2019. Sustainable Development in Polish Regions: A Shift-Share Analysis. *Polish Journal of Environmental Studies* 28: 565–75. [CrossRef] [PubMed]

Dembińska, Izabela, Sabina Kauf, Agnieszka Tłuczak, Katarzyna Szopik-Depczyńska, Łukasz Marzantowicz, and Giuseppe Ioppolo. 2022. The impact of space development structure on the level of ecological footprint—Shift share analysis for European Union countries. *Science of the Total Environment* 851: 157936. [CrossRef] [PubMed]

Dunn, Edgar S. 1960. A statistical and analytical technique for regional analysis. *Papers of the Regional Science Association* 6: 97–112. [CrossRef]

Fauber, Kenise Hamilton. 2022. *West Virginia's Automotive Manufacturing Industry*. Available online: https://wvexecutive.com/west-virginias-automotive-manufacturing-industry/ (accessed on 1 July 2024).

Franconi, Luisa, Marianna Mantuano, and Daniela Ichim. 2024. Population grid and location quotient of land cover to capture the urban-rural nature of labour market areas in Italy. *GeoJournal* 89: 6. [CrossRef]

Giannakis, Elias, and Adriana Bruggeman. 2015. Economic crisis and regional resilience: Evidence from Greece. *Papers in Regional Science* 96: 451–76. [CrossRef]

Goschin, Zizi. 2014. Regional growth in Romania after its accession to EU: A shiftshare analysis approach. *Procedia Economics and Finance* 15: 169–75. [CrossRef]

Herath Bandara, S. 2024. Understanding Workforce Transitions in West Virginia: Exploring Shift-share and Location Quotient Analysis. *Presented at the 2024 Agricultural & Applied Economics Association Annual Meeting*, New Orleans, LA, USA, July 28–30.

Herath, Janaranjana, Peter V. Schaeffer, and Tesfa G. Gebremedhin. 2013. Employment change in LDs of West Virginia: A dynamic spatial shift-share analysis. *American Journal of Rural Development* 1: 99–105.

Herath, Janaranjana, Tesfa Gebremedhin, and Blessing M. Maumbe. 2010. A Dynamic Shift-Share Analysis of Economic Growth in West Virginia. *Journal of Rural and Community Development* 6: 155–69. Available online: https://www.researchgate.net/profile/Janaranjana_Herath/publication/236646929_A_dynamic_shift_share_analysis_of_economic_growth_in_West_Virginia/links/00463518bef1e8a5f4000000.pdf (accessed on 1 July 2024).

HRSA. 2022. Overview of the State—West Virginia—2022. US Department of Health and Human Services. Available online: https://mchb.tvisdata.hrsa.gov/Narratives/Overview/94a29364-c888-407c-9d0e-80a05fe5434d (accessed on 1 July 2024).

IBISWorld. 2024. West Virginia Economic Profiles. Available online: https://www.ibisworld.com/united-states/economic-profiles/west-virginia/ (accessed on 15 June 2024).

Ireland, Timothy.C., and Ronald L. Moomaw. 1981. The Competitive Effect in Shift-Share Analysis: A Will of the Wisp? *The Review of Regional Studies* 11: 72–82. [CrossRef]

Knudsen, Daneil C. 2000. Shift Share Analysis: Further examination of models for the description of economic change. *Socio-Economic Planning Sciences* 34: 17–198. [CrossRef]

Leonhardt, Kent. 2021. *OP ED: West Virginia Grown: Local Agriculture's Impact And Outlook*. Available online: https://agriculture.wv.gov/2021/10/18/op-ed-west-virginia-grown-local-agricultures-impact-and-outlook/ (accessed on 15 June 2024).

Markusen, Ann R., Helzi Noponen, and Karl Driessen. 1991. International trade, productivity, and U.S. regional job growth: A shift-share interpretation. *International Regional Science Review* 14: 15–39. [CrossRef]

Massie, Ashtin, Maria Castillo, and Joe Daniel. 2023. Affordable Energy in West Virginia Starts with Economic Dispatch. Utilitydive. Available online: https://www.utilitydive.com/news/affordable-energy-west-virginia-coal-plants-economic-dispatch-pjm/690309/ (accessed on 1 June 2024).

McNamara, Kevin T. 1991. *Employment Growth in Indiana: A State and Regional Analysis*. West Lafayette: Purdue University Corporative Extension Service.

Melachroinos, Konstantinos A. 2002. European Integration and the Spatial Dynamics of Manufacturing-Employment Change. *Environment and Planning* 34: 2017–36. [CrossRef]

Miller, Olivia. 2022. Ladies Leading in Chemical Manufacturing. Available online: https://wvexecutive.com/ladies-leading-in-chemical-manufacturing/ (accessed on 15 June 2024).

Morrissey, Karyn. 2014. A location quotient approach to producing regional production multipliers for the Irish economy. *Papers in Regional Science* 95: 491–507. [CrossRef]

National Center for Education Statistics. 2022. Public High School Graduation Rates—National. Available online: https://nces.ed.gov/programs/coe/pdf/2021/coi_508c.pdf (accessed on 15 June 2024).

Prats, Germán Martínez, and Aida Armenta Ramirez. 2018. Analysis of the Behavior of a Regional Economy through the Shift-Share and Location Quotient Techniques. *Management Dynamics in the Knowledge Economy* 6: 553–68. [CrossRef]

Richardson, Harry. 1973. *Regional Growth Theory*. London: Macmillan.

Richardson, Harry. 1978. *Regional and Urban Economics*. Harmondsworth: Penguin.

Sablin, Kirill S., Elena Sh. Kagan, and Alexander A. Sharov. 2018. Assessment of resource regions' readiness for comprehensive exploitation of mineral resources based on shift-share analysis. *Earth and Environmental Science* 206: 012018. [CrossRef]

Sampe, Hisky Robinson, Mohammed Ali Berawi, Djoni Hartono, and Mustika Sari. 2023. Determining dominant economic sectors in Central Sumatera areas connected to the trans sumatera toll road (TSTR) using the location quotient method. *AIP Conference Proceedings* 2847: 050013. [CrossRef]

Sarder, M. D., Syedmohsen Hossieini, and Mohammad Mayyas. 2018. Reshoring and Its Economic Impact Analysis Using Location Quotient. Paper presented at the 2018 IISE Annual Conference, Orlando, FL, USA, May 19–22; Peachtree Corners: Institute of Industrial and Systems Engineers (IISE).

Selting, Anne C., and Scott Loveridge. 1994. Testing Dynamic Shift-Share. *Journal of Regional Analysis and Policy* 24: 23–41.

Sheng, Ruxu, Rong Zhou, Ying Zhang, and Zidi Wang. 2021. Green Investment Changes in China: A Shift-Share Analysis. *International Journal of Environmental Research and Public Health* 18: 6658. [CrossRef]

Shi, Chun-Yun, and Yang Yang. 2008. Review of Shift Share Analysis and Its Application in Tourism. *International Journal of Management Perspectives* 1: 21–30.

Sperow, Charles. 2023. Agriculture. E-WV, The West Virginia Encyclopedia. Available online: https://www.wvencyclopedia.org/articles/166#:~:text=Whileaveragefarmsizesremained,Hardy,Monroe,andPreston (accessed on 1 June 2024).

U.S. Census Bureau. 2022. U.S. School System Current Spending Per Pupil by Region: Fiscal Year 2020. Available online: https://www.census.gov/library/visualizations/2022/comm/spending-per-pupil.html (accessed on 15 June 2024).

Virginia-map.com. 2022. *Map of West Virginia*. Virginia-map.com. Available online: https://virginia-map.com/wp-content/uploads/2022/11/map-of-west-virginia.png (accessed on 15 July 2024).

West Virginia Agriculture. 2023. Farm Flavor. Available online: https://farmflavor.com/west-virginia-agriculture/ (accessed on 1 June 2024).

West Virginia Construction, and Building Trends. 2023. IBISWorld 2023. Available online: https://www.ibisworld.com/united-states/economic-profiles/west-virginia/#BuildingSection (accessed on 15 June 2024).

West Virginia Transportation by the Numbers. 2021. TRIP. Available online: https://tripnet.org/wp-content/uploads/2021/02/TRIP_West_Virginia_BTN_Report_February_2021.pdf (accessed on 1 June 2024).

Williams, Heather. 2012. *Moving the Mountain State Forward: 21st Century Education*. Available online: https://wvexecutive.com/moving-the-mountain-state-forward-21st-century-education/ (accessed on 1 June 2024).

Wilson, Peter, and Ting Su Chern. 2005. A Dynamic Shift Share Analysis of the Electronics Export Market 1988–2001: Can the NIEs Compete with China? Department of Economics, SCAPE Working Paper Series, Paper No. *2005/07-May2005.* Available online: https://www.nt2.fas.nus.edu.sg/es/pub/wp-scape/0507.pdf (accessed on 15 June 2024).

Witt, Tom, and Mark Fletcher. 2005. Tourism and the West Virginia Economy. *Bureau of Business and Economic Research, West Virginia University.* Available online: https://researchrepository.wvu.edu/bureau_be/192/ (accessed on 18 August 2007).

Witt, Tom, and Sebastian Leguizamon. 2007. Tourism and the West Virginia Economy February 2007. Bureau of Business and Economic Research, West Virginia University. Available online: https://researchrepository.wvu.edu/bureau_be/146/ (accessed on 18 August 2007).

WVHEPC (West Virginia Higher Education Policy Commission). 2023. *College-Going Rate*. Available online: https://www.wvhepc.edu/resources/data-and-publication-center/cgr/ (accessed on 1 July 2024).

Young, Charles. 2019. Health Care in WV: State faces Unique Set of Challenges, Opportunities. *West Virginia News*. Available online: https://www.wvnews.com/news/wvnews/health-care-in-wv-state-faces-unique-set-of-challenges-opportunities/article_18a140c9-7fe0-5ac7-8fd4-56b8700ea414.html (accessed on 15 June 2024).

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The Impact of Gastronomic Tourism on the Regional Economy of Thailand: Examined by the Dynamic I-O Model after the Decline of COVID-19

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Abstract: It is reasonable to state that gastronomic tourism is an efficient tool that has the potential to refresh Thailand's macroeconomic viability. With the aim of becoming a hub of tourism in Southeast Asia, Thailand's tourism industry must urgently address and sustainably integrate gastronomic activities to navigate the troubled situation caused by its decline after the COVID-19 pandemic. This has led the authors to conduct a deep study on a regional input–output (I-O) table analysis for Thailand's tourism system, specifically focusing on gastronomic activities and tourism industries. The tourism I-O data used in this study come from the official source provided by the Thailand Ministry of Tourism and Sport. Empirically, the results of the dynamic regional I-O model predict that Bangkok and its surrounding areas are the heart of gastronomic tourism development, driving income into Thailand's economy. The eastern region stands as the second-largest area of gastronomy tourism, generating a positive impact on Thailand's economy. On the other hand, the Northeast of Thailand receives less income from gastronomy tourism despite being the largest area in the country. Ultimately, there should be a greater emphasis on gastronomy tourism policies in order to fully maximize their potential for tourism development, stimulating every part of Thailand during the economic depression caused by COVID-19. Moreover, gastronomy tourism has the potential to play an important role in driving economic growth through the combination of cuisine and tourism development.

Keywords: tourism I-O data; decline of COVID-19; gastronomic tourism; reginal of Thai's economy; dynamic regional input-output model; prediction; stimulating

1. Introduction

Nowadays, gastronomy generates significant income for the global tourism industry by offering cultural experiences and influencing travelers to engage in food tourism. According to market research, the global gastronomy tourism market was valued at USD 237.7 billion in 2020 and is predicted to grow at an average rate of 14.2% per year from 2021 to 2028. For the Thai economy, gastronomy tourism may be a potential key factor in driving the tourism industry of Thailand after its decline caused by the COVID-19 pandemic.

The policy of promoting high volumes of inbound tourists has produced good results in tourism revenues for Thailand's economy for several decades (Chaitip and Chaiboonsri 2009; TAT 2019). However, most of the tourism income, especially spending on gastronomic activities in 2020, is generated by centralized travel in capital cities (Thailand Ministry of Tourism and Sports 2019) (see Figure 1). Figure 1 confirms the abnormal distribution of travel styles (spending on gastronomic activities) in Thailand's regional areas. Bangkok and its surrounding areas are commonly regarded as the center of Thailand's tourist destinations, accounting for approximately 32.7% of tourist arrivals for gastronomy spending.

However, the problem lies in monitoring regional distributions. The Northeastern region is the largest region in Thailand, but it only accounts for 5.74% of inbound tourist spending on gastronomy activities.

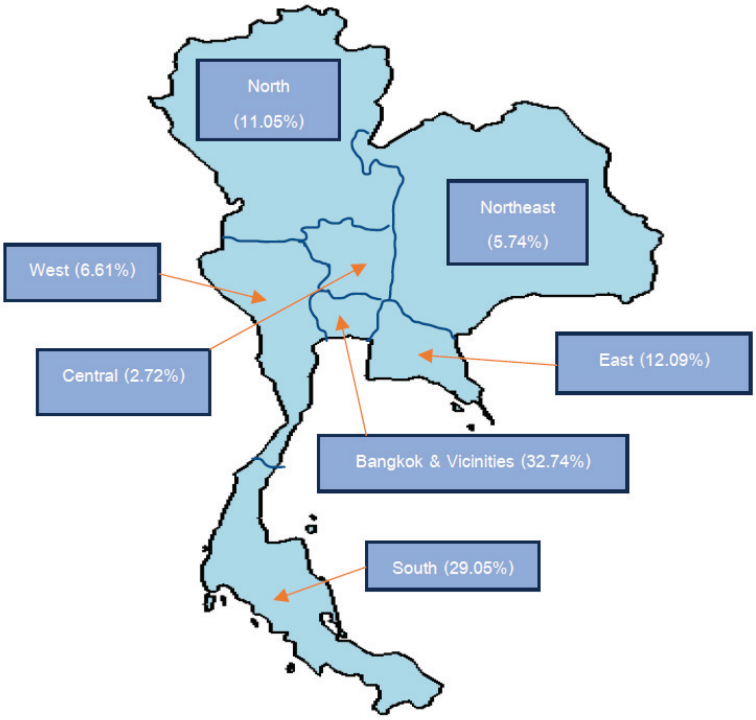

Figure 1. The distribution of travel styles, especially gastronomy tourism spending, in Thailand. Source: Thailand Ministry of Tourism and Sports (2019).

On the other hand, the Southern region, despite having a smaller area, attracts 29.05% of tourists who choose to travel and spend on gastronomy activities in Thailand. There is also an imbalance in travel styles for gastronomy activity between the Western and Eastern regions (Thailand Ministry of Tourism and Sports 2019). Additionally, the Central region, which is the area connected to the capital city, surprisingly attracts the minimum number of tourists for gastronomy spending. Consequently, this information reveals the problem of tourism management, especially in the context of gastronomy tourism development, in many parts of Thailand. Therefore, achieving balanced economic development for every part of Thailand based on the gastronomy tourism industry should be a crucial topic for long-term prosperity without harming the environment (United Nations (UN) Sustainable Development Goals (SDGs)[1]).

Besides inefficient management for promoting rural tourism in Thailand causing the country to miss a chance to become the central tourism destination in Southeast Asia, Thailand tourism was collapsed by the COVID-19 pandemic that started in the fourth quarter in 2019. Figure 2 shows the dramatic fall in tourism arrivals during 2019 and 2020. This shock immediately shut down international and domestic tourism activities and caused small businesses to continuously decline due to declining tourism markets. However, rural tourism and agricultural activities can play a key role in refreshing the market. It is recommended that gastronomy tourism (also commonly referred to "food tourism" or "culinary tourism") be politically reconsidered. Gastronomy tourism has currently become a major force in travel and local development (Kiráľová and Hamarneh 2017; Rachão et al. 2019; Rinaldi 2017). Thailand has gained advantages because of its highly logistically favorable location. Additionally, every single area in the country has a significant level of cultural uniqueness, including unique local foods and stories.

In other words, consumers travel for food and try to seek experiences that drive the destination choices of people worldwide. Interestingly, many checking points have made highlighting food and drink offerings as a key part of their messaging strategy. Ultimately, gastronomy tourism is the ideal way to connect agricultural employment with small businesses (SMEs) in the upcoming future, thus helping to promote sustainable development according to the 2030 SDGs (Goal#2) of the United Nations (2020), sustainable food and agriculture by FAO (2020), and creative economy by UNESCO (2013).

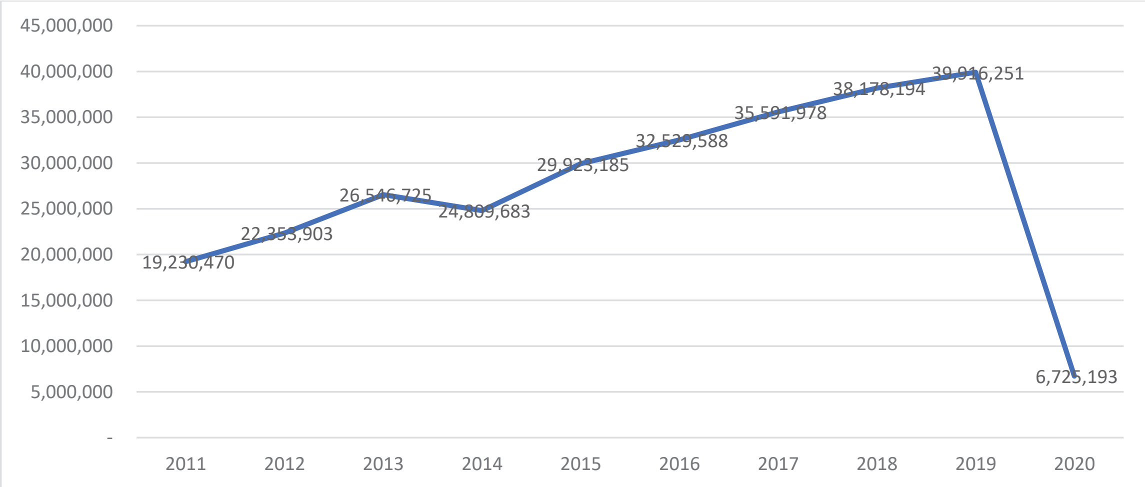

Figure 2. The number of tourist arrivals (person) in Thailand from 2016 to 2020.

2. The Review of Tourism Management and Reginal Input–Output Analysis

The positive consequences of efficient tourism management—job creation, the expansion of investments, infrastructure development, and improvements in standard of well-being—have been found in many host areas (Brankov et al. 2019; Liu and Var 1986; Mitchell and Reid 2001). However, all tourism development has to face trade-offs between what investors consider to be benefits and the costs of those benefits. In terms of the situation in this article, investors are government authorities who are curious about people's votes. Hence, substantial policy implementations are the key motivation for regional input–output (I-O) analyses. A regional I-O model permits a deep investigation of certain problems in a space economy, referring to changing regional and interregional structures based on a set of restrictive assumptions (Isard 1951). For the historical research review, regional I-O analysis is broadly used to macroeconomically monitor crucial sectors; for example, Rey (2000) started to integrate regional econometric tools which arise from multiregional linkages and spatial effects and I-O modeling simultaneously. Santos (2005) studied regional decomposition in the I-O table for capacitating a more focused and therefore a more accurate analysis of interdependencies for regions of interest in the 1997 US Economy. Zhang et al. (2016) applied a multi-regional I-O analysis to compute economic impacts in a Chinese industry which intends to withdraw demand-driven water. Hardadi and Pizzol (2017) employed multiregional I-O analysis to incorporate the environmental dimension and the social dimension in extending the theoretical framework, thus enabling advancement in the use of social life cycle assessment. The characterization of labor-related impacts was the main issue in highlighting unemployment impacts on human productivity in the United States.

Stadler et al. (2018) applied multiregional I-O to environmentally extend a comprehensive description of the global economy and analyzed its effects on the environment. They gathered data from the EE MRIO databases which range from 1995 to 2011 for 44 countries, thus five regions of the world. An important conclusion of the paper was that the high sectorial detail and wide spectrum of the I-O data allow for both economy-wide assessments and the identification of environmental hotspots (i.e., energy production, food, and mobility). In contrast to I-O data for macroeconomic research, it is rare for tourism sectorial analysis to be empirically focused. Because of the difficulties of official data collection and accessibility, the huge gaps in research are the impetus to create official tourism I-O tables to describe multipliers of tourism activities and affiliated industrial sectors. Zimmermann et al. (2013) were among the few tourism I-O researchers, and they conducted research in Mecklenburg–Western Pomerania, Germany. This paper combined regional tourism economic structures and I-O analyses to quantify output, value-added, and wage bills referring to tourists' demands when coming to the German state. As an inspiration, the current paper applied the idea of dynamic regional I-O analysis for monitoring 'Gastronomy' tourism sectors affecting Thailand's economic viability, based on the initial assumption that the COVID-19 pandemic can be efficiently controllable in Thailand.

3. The Dynamic I-O Model for Regional Analysis of Thailand

The dynamic I-O model has been applied to analysis in the tourism industry context beginning with Dwyer et al. (2010), who explained how to use this model to evaluate the impact of tourism policy in the world tourism sector. Moreover, in 2013, Zimmermann and Hirschfeld utilized this model to analyze the impact of climate change on tourism development in Mecklenburg–Western Pomerania, Germany. The dynamic I-O model continues to work very well. Kronenberg et al. (2018) utilized the dynamic I-O model to evaluate tourism's economic contribution in a regional context for Sweden. However, in the gastronomy tourism sector, there are still only a few research articles that have applied this model to evaluate its economic impact, especially the impact of tourism on the economy based on the context of regional gastronomic economic impact. Therefore, this research article would like to utilize the dynamic I-O model to examine the economic impact of gastronomy tourism in several areas in Thailand.

For the beginning of the methodological section, the condition is to start with a concept of single-region analysis. The research scope focuses on Thailand's tourism sector, specifically considering gastronomic activities. Inside the country, we, therefore, proceed to a model that attempts to capture not just intra-regional interactions but also interregional linkages. The fundamental aim of single-region I-O models is to measure the impact on regional output of changes in regional final demand. National output and final demand are demonstrated as the following vectors:

$$X_N = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

$$Y_N = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}$$

To address the economy as a whole, inside the equation $(I - A) \cdot x = y$, the matrix A can be defined as the classification of national commodities:

$$A = \begin{bmatrix} a_{11} & . & . & a_{1n} \\ a_{21} & . & . & a_{2n} \\ . & . & . & . \\ a_{n1} & . & . & a_{nn} \end{bmatrix} \quad (1)$$

It is necessary to extensively modify the matrix (A) for a regional analysis of Thailand; the process followed here is below.

$$P_i^R = \frac{(x_i^R - e_i^R)}{(x_i^R - e_i^R + M_i^R)}$$

where

P_i^R = the proportion of output for the production sector (i) in a specified region (R). Seven regions of Thailand are compared with the total output of the same production sector (i) of the whole of Thailand:

x_i^R = the total output of the production sector (i) in a specified region (R) of Thailand

e_i^R = the export output of the production sector (i) in the specified region (R) of Thailand

M_i^R = the import output of the production sector (i) in the specified region (R) of Thailand

In the regional case, the matrix A of the I-O model which would be applied in the regional analysis of Thailand needs to be modified by multiplying it by P_i^R (Equation (1)).

$$P^R = \begin{bmatrix} P_{11}^R \\ P_{12}^R \\ . \\ . \\ . \\ P_{1i}^R \end{bmatrix}, \; i = 1, \ldots, n \; (n = \text{production sector}(i)\text{of Thailand})$$

$$\hat{P} = < P >= \begin{bmatrix} P_{11}^R & 0 & . & 0 \\ 0 & P_{12}^R & . & 0 \\ 0 & . & . & 0 \\ 0 & . & . & P_{1i}^R \end{bmatrix}$$

Then,

$$\hat{P}A = \hat{P}.A = \begin{bmatrix} a_{11} & . & . & a_{1n} \\ a_{21} & . & . & a_{2n} \\ . & . & . & . \\ a_{n1} & . & . & a_{nn} \end{bmatrix} = A_R$$

To modify the previous composed vectors **X** and **Y**, the formation of the model can be demonstrated as follows (Miller and Blair 2009; Sargento 2009): (see Equation (2))

$$\begin{bmatrix} (I - A_R) & -A_R \\ -A_R & (I - A_R) \end{bmatrix} \begin{bmatrix} X_R \\ X_R \end{bmatrix} = \begin{bmatrix} Y_R \\ Y_R \end{bmatrix} \Leftrightarrow$$
$$\begin{bmatrix} X_R \\ X_R \end{bmatrix} = \begin{bmatrix} (I - A_R) & -A_R \\ -A_R & (I - A_R) \end{bmatrix}^{-1} \begin{bmatrix} Y_R \\ Y_R \end{bmatrix} \quad (2)$$

This equation quantifies the nationwide effect on the total output for each product category, driven by an exogeneous change in the demand of either one or more national sectors' and/or one or more regional sectors' outputs. Moreover, the formula of the Dynamic I-O model for a regional analysis of Thailand must be transformed again (see Equations (3) and (4)).

$$X_R = (1 - A_R)^{-1} Y_R \quad (3)$$

$$(I + A_R + B_R) X_R^t - B X_R^{t+1} = Y_R^t \quad (4)$$

where

I = the identity matrix

B_R = the capital coefficient matrix of a specified region of Thailand

X_R^t = the output of a specified region of Thailand

Y_R^t = the final demand of a specified region of Thailand

When T = 3, i.e., three years, $((I + A_R + B_R) = G_R)$

$$G_R X_R^0 - B_R X_R^1 = Y_R^0 \quad (5)$$

$$G_R X_R^1 - B_R X_R^2 = Y_R^1 \quad (6)$$

$$G_R X_R^2 - B_R X_R^3 = Y_R^2 \quad (7)$$

$$G_R X_R^3 - B_R X_R^4 = Y_R^3 \quad (8)$$

This calculation technique has been implemented in this research article for the four linear equations already mentioned above, in which it was necessary to delete Equation (8). Therefore, the overall input/output results of the estimation by the Dynamic I-O model for the regional analysis of Thailand are stated in Equations (9)–(11).

$$X_R^0 = G_R^{-1}(Y_R^0 + B_R X_R^1) \quad (9)$$

$$X_R^1 = G_R^{-1}(Y_R^1 + B_R X_R^2) \quad (10)$$

$$X_R^2 = G_R^{-1}(Y_R^2 + B_R X_R^3) \quad (11)$$

From Equations (9) and (10), it can be explained that X_R^0, X_R^1, and X_R^2 are the output of the Dynamic I-O model for the regional analysis of Thailand in one year each. However, this research article only focuses on a one-year prediction (2021) based on gastronomic tourism's economic impact on the regional economy of Thailand. The significant multiplier measurement for the Dynamic I-O model can thus be computed by G_R^{-1}.

4. Data Review

4.1. The COVID-19 Pandemic and Thailand Gastronomic Tourism

At the moment of writing, Thailand has efficiently controlled the COVID-19 pandemic since the detection of the outbreak in 2019. With confidence underlying a strong public health system and the country's prior experiences with major breakouts, the number of infections is impressively low (World Health Organization 2020). However, strict control has inevitably caused a depression in the country's economy. International tourism is the most harmed sector. Hence, domestic purchasing power is intensively considered. Gastronomic tourism is an activity directly connected with domestic consumption. Table 1 details information that supports this idea. In 2020, almost 736,052 million Baht was contributed to the economy of Thailand by domestic gastronomic spending. Bangkok (the capital city) together with the vicinities and provinces of the Southern region were the leading gastronomy destinations, gaining record gastronomy spending of 240,984 and 213,820 million Baht, respectively. The Northern and Eastern regions were comparatively minor gastronomy tourism destinations. The Northeastern region, the largest area in Thailand, generated a similar income via gastronomy tourism to the Western region, which is one of the smallest areas in the country. Lastly, the Central region was the only area in which gastronomy tourism was not the major source of income.

Another important detail represented in Table 1 is the initial predictive Beta for a dynamic I-O computation. Based on an optimistic foresight for 2021 GDP growth because of the efficient control of COVID-19 outbreaks, 5% is the initial rate used to set the portions of regional outputs. This therefore confirms that Thailand is facing an unsustainable level of development in gastronomy tourism because the tourism destinations are intensively concentrated in Bangkok and the Southern region. These areas have been reported to be at risk of causing outbreaks of the virus since December 2020. New cases observed in a shrimp market in Samut Sakhon province near Bangkok are migrant workers from neighboring countries. Additionally, seafood from the province is widely delivered to the Southern region (Giri 2021).

Using the official Thailand tourism I-O table provided by the Thailand Ministry of Tourism and Sports, 23 sectors (see Table 2) pertaining to gastronomic tourism were selected from 89 industrial activities in the 2017 I-O table.

The selected sectors are defined as those that impact gastronomy tourism in Thailand through multiplier effects (Benedek et al. (2020)), because all 23 sectors play a significant role in the food industry, whether upstream, midstream, or downstream. In addition, the food industry supplies food to gastronomy tourism[2] when this ecosystem of both moves up together, which empowers the drive for the economy of Thailand to achieve more after its COVID-19-related decline. However, these data will then be processed in the relating to dynamic regional I-O forecasting.

Table 1. The situation of gastronomy tourism in Thailand during 2020 and initial predictive Beta for the dynamic I-O model.

Regions of Thailand	Spending in Gastronomic Activities in 2020 (Million Baht)	Portion (%)	Initial Beta for the Dynamic I-O Model (Predictive +5% for 2021 (GDP))
Bangkok & Vicinities	240,984	32.74	0.0164
South	213,820	29.05	0.0145
East	88,961	12.09	0.0060
North	81,355	11.05	0.0055
West	48,644	6.61	0.0033
Northeast	42,276	5.74	0.0029
Central	20,012	2.72	0.0010
Total	736,052	100.00	0.0500

Table 2. The collected gastronomic tourism I-O sectors based on the 2017 tourism I-O table.

Sectors I-O	Definition
IO-001	Paddy
IO-002	Maize
IO-003	Cassava
IO-004	Beans and Nuts
IO-005	Vegetables and Fruits
IO-006	Sugarcane
IO-007	Rubber (Latex)
IO-008	Other Crops
IO-009	Livestock
IO-010	Forestry
IO-011	Fishery
IO-012	Slaughtering
IO-013	Processing and Preserving of Foods
IO-014	Rice and Other Grain Milling
IO-015	Sugar Refineries
IO-016	Other Foods
IO-017	Animal Food
IO-018	Beverages
IO-019	Tobacco Processing and Products
IO-020	Food and beverage serving activities
IO-021	Other food service
IO-022	Drinking Places
IO-023	Other beverage services

Source: Thailand Ministry of Tourism and Sports (2020).

4.2. Result of Dynamic Regional Input-Output Analysis

Based on the high-performance areas identified for as gastronomy tourism destinations, further details can be found in Table 3. This table shows the details of a comparison of dynamic regional multipliers' predictions between Bangkok and vicinities and the Southern provinces; it is clear that the performance of the capital city and its surrounding neighborhoods in terms of gastronomic tourism destinations is almost higher than that of its counterpart. For example, a premium high productive sector is animal food industries, while high productive sectors include sugar industries, slaughtering companies, even food and beverage serving activities, etc. However, there are some interesting points; for example, state industries manufacturing beans and nuts perform better in the Southern region rather than the capital city because of the lack of farming area in the latter. Moreover, industries producing preserved foods in the Southern region contain the higher multiplier than those in its counterpart because of its greater raw material sources. To summarize, gastronomy tourism in Thailand does not have many options for renewal. Policies to promote gastronomic activities should be initially implemented in the area of the capital city and its neighbors.

Table 3. The comparison of dynamic multiplier predictions between Bangkok and vicinities and the Southern region in Thailand based on gastronomic sectoral activities.

Sector I-O	**Overall Multiplier**	**Dynamic Multiplier**		**Interpretation**
		BKK-Vicinities (1)	**Southern (2)**	
Paddy	1.6071 *	1.0107	1.00943	(1) > (2)
Maize	1.7724 *	1.0126	1.01112	(1) > (2)
Cassava	1.8358 *	1.0119	1.01054	(1) > (2)
Beans and Nuts	2.1238 **	1.0141	1.01247	(1) < (2)
Vegetables and Fruits	1.7794 *	1.0113	1.01003	(1) > (2)
Sugarcane	2.0750 **	1.0156	1.01382	(1) > (2)
Rubber (Latex)	1.4219 *	1.0064	1.00566	(1) > (2)
Other Crops	1.8989 *	1.0125	1.01102	(1) > (2)
Livestock	2.3209 **	1.0094	1.00833	(1) > (2)
Forestry	1.5803 *	1.0049	1.00435	(1) > (2)
Fishery	2.3247 **	1.0108	1.00958	(1) > (2)
Slaughtering	2.7258 **	1.0130	1.01149	(1) > (2)
Processing and Preserving of Foods	2.7481**	1.0140	1.01236	(1) < (2)
Rice and Other Grain Milling	2.2944 **	1.0213	1.01887	(1) > (2)
Sugar Refineries	2.2143 **	1.0101	1.00891	(1) > (2)
Other Foods	2.5331 **	1.0118	1.01038	(1) > (2)
Animal Food	3.0458 ***	1.0147	1.01297	(1) > (2)
Beverages	2.2307 **	1.0101	1.00888	(1) > (2)
Tobacco Processing and Products	1.3877 *	1.0044	1.00388	(1) > (2)
Food and beverage serving activities	2.7014 **	1.0133	1.01174	(1) > (2)
Other food service	2.5010 **	1.0110	1.00969	(1) > (2)
Drinking Places	2.1593 **	1.0093	1.00817	(1) > (2)
Other beverage services	1.9026 *	1.0075	1.00662	(1) > (2)

Note: * indicates a gastronomic sectoral multiplier > 1 (productive sector). ** indicates a gastronomic sectoral multiplier > 2 (high productive sector). *** indicates a gastronomic sectoral multiplier > 3 (premium high productive sector).

Regarding the potential areas for gastronomy tourism destinations, more details can be found in Table 4. The results indicate that provinces in the Eastern region perform better overall than those in the Northern region as primary gastronomy tourism destinations. The advantages of the eastern region are sea-connecting and multi-farming provinces such as Chonburi, Rayong, Chanthaburi, and Trad. These provinces have agricultural sectors—paddy, maize, cassava, beans, nuts, and farms for vegetables and fruits—which are essential for driving the downstream of gastronomy tourism. Additionally, beverage and food service companies in the Eastern region are predicted to be more active than those in the Northern region. However, with the lack of agricultural spaces and living costs in the Eastern region, gastronomic activities such as slaughtering, preserved foods, and rice farming perform better in Northern provinces. To summarize this issue, Eastern and Northern areas can be defined as a good choice to continue the sustainable development for gastronomy tourism.

Table 4. The comparison of dynamic multipliers between the Eastern region and Northern region in Thailand based on gastronomic sectoral activities.

Sector I-O	Overall Multiplier	Dynamic Multiplier		Interpretation
		Eastern (3)	Northern (4)	
Paddy	1.6071 *	1.0039	1.0036	(3) > (4)
Maize	1.7724 *	1.0046	1.0042	(3) > (4)
Cassava	1.8358 *	1.0043	1.0040	(3) > (4)
Beans and Nuts	2.1238 **	1.0051	1.0047	(3) > (4)
Vegetables and Fruits	1.7794 *	1.0041	1.0038	(3) > (4)
Sugarcane	2.0750 **	1.0057	1.0052	(3) > (4)
Rubber (Latex)	1.4219 *	1.0023	1.0021	(3) > (4)
Other Crops	1.8989 *	1.0045	1.0042	(3) > (4)
Livestock	2.3209 **	1.0034	1.0031	(3) > (4)
Forestry	1.5803 *	1.0018	1.0016	(3) > (4)
Fishery	2.3247 **	1.0039	1.0036	(3) > (4)
Slaughtering	2.7258 **	1.0039	1.0043	(3) < (4)
Processing and Preserving of Foods	2.7481 **	1.0046	1.0047	(3) < (4)
Rice and Other Grain Milling	2.2944 **	1.0043	1.0071	(3) < (4)
Sugar Refineries	2.2143 **	1.0051	1.0034	(3) > (4)
Other Foods	2.5331 **	1.0041	1.0039	(3) > (4)
Animal Food	3.0458 ***	1.0057	1.0049	(3) > (4)
Beverages	2.2307 **	1.0023	1.0033	(3) < (4)
Tobacco Processing and Products	1.3877 *	1.0045	1.0015	(3) > (4)
Food and beverage serving activities	2.7014 **	1.0048	1.0044	(3) > (4)
Other food service	2.5010 **	1.0040	1.0036	(3) > (4)
Drinking Places	2.1593 **	1.0034	1.0031	(3) > (4)
Other beverage services	1.9026 *	1.0027	1.0025	(3) > (4)

Note: * indicates a gastronomic sectoral multiplier > 1 (productive sector). ** indicates a gastronomic sectoral multiplier > 2 (high productive sector). *** indicates a gastronomic sectoral multiplier > 3 (premium high productive sector).

The optional areas for gastronomy tourism destinations are detailed in Table 5. This table provides a clear comparison, demonstrating that the Western region outperforms the Northeastern region in terms of agricultural activities and services related to beverages and food. However, it is noteworthy that there is a significant disparity in the sizes of these regions. The Northeastern region, being the largest in Thailand, comprises more provinces than the Western region (Thailand Ministry of Natural Resources and Environment 2021). Despite this, the economic multipliers of the Northeastern region have only a marginal impact on enhancing gastronomy tourism in the country. In summary, while both regions serve as viable alternatives for gastronomic activities, the Western region offers more value for promoting gastronomy tourism, especially in light of budget constraints. The minor area for gastronomy tourism destinations is detailed in Table 6. The Central region has the lowest multipliers impacting Thailand's gastronomy tourism. With multiplier values equivalent to one, this implies that investing budgets to initiate gastronomic tourism activities in this region would only achieve break-even development.

Table 5. The comparison of dynamic multiplier predictions between Northeastern region and West region in Thailand based on gastronomic sectoral activities.

Sector I-O	Overall Multiplier	Dynamic Multiplier		Interpretation
		West (5)	Northeastern (6)	
Paddy	1.6071 *	1.0021	1.0019	(5) > (6)
Maize	1.7724 *	1.0025	1.0022	(5) > (6)
Cassava	1.8358 *	1.0024	1.0021	(5) > (6)
Beans and Nuts	2.1238 **	1.0028	1.0025	(5) > (6)
Vegetables and Fruits	1.7794 *	1.0023	1.0020	(5) > (6)
Sugarcane	2.0750 **	1.0031	1.0027	(5) > (6)
Rubber (Latex)	1.4219 *	1.0013	1.0011	(5) > (6)
Other Crops	1.8989 *	1.0025	1.0022	(5) > (6)
Livestock	2.3209 **	1.0019	1.0016	(5) > (6)
Forestry	1.5803 *	1.0010	1.0009	(5) > (6)
Fishery	2.3247 **	1.0022	1.0019	(5) > (6)
Slaughtering	2.7258 **	1.0026	1.0023	(5) > (6)
Processing and Preserving of Foods	2.7481 **	1.0028	1.0024	(5) > (6)
Rice and Other Grain Milling	2.2944 **	1.0043	1.0037	(5) > (6)
Sugar Refineries	2.2143 **	1.0020	1.0018	(5) > (6)
Other Foods	2.5331 **	1.0023	1.0021	(5) > (6)
Animal Food	3.0458 ***	1.0029	1.0026	(5) > (6)
Beverages	2.2307 **	1.0020	1.0018	(5) > (6)
Tobacco Processing and Products	1.3877 *	1.0009	1.0008	(5) > (6)
Food and beverage serving activities	2.7014 **	1.0026	1.0023	(5) > (6)
Other food service	2.5010 **	1.0022	1.0019	(5) > (6)
Drinking Places	2.1593 **	1.0018	1.0016	(5) > (6)
Other beverage services	1.9026 *	1.0015	1.0013	(5) > (6)

Note: * indicates a gastronomic sectoral multiplier > 1 (productive sector). ** indicates a gastronomic sectoral multiplier > 2 (high productive sector). *** indicates a gastronomic sectoral multiplier > 3 (premium high productive sector).

Therefore, while this region is less ideal for promoting gastronomy tourism, it presents a better opportunity for sustainable development as a provider of raw gastronomic materials for major tourist destination cities.

Table 6. Dynamic multiplier predictions for the Central region in Thailand based on gastronomic sectoral activities.

Sector I-O	Overall Multiplier	Dynamic Multiplier
		Central (7)
Paddy	1.6071 *	1.0008
Maize	1.7724 *	1.0009
Cassava	1.8358 *	1.0008
Beans and Nuts	2.1238 **	1.0010
Vegetables and Fruits	1.7794 *	1.0008
Sugarcane	2.0750 **	1.0011
Rubber (Latex)	1.4219 *	1.0005
Other Crops	1.8989 *	1.0009
Livestock	2.3209 **	1.0006
Forestry	1.5803 *	1.0003
Fishery	2.3247 **	1.0007
Slaughtering	2.7258 **	1.0008
Processing and Preserving of Foods	2.7481 **	1.0009
Rice and Other Grain Milling	2.2944 **	1.0015
Sugar Refineries	2.2143 **	1.0006
Other Foods	2.5331 **	1.0007
Animal Food	3.0458 ***	1.0009
Beverages	2.2307 **	1.0006
Tobacco Processing and Products	1.3877 *	1.0003
Food and beverage serving activities	2.7014 **	1.0008
Other food service	2.5010 **	1.0007
Drinking Places	2.1593 **	1.0006
Other beverage services	1.9026 *	1.0005

Note: * indicates a gastronomic sectoral multiplier > 1 (productive sector). ** indicates a gastronomic sectoral multiplier > 2 (high productive sector). *** indicates a gastronomic sectoral multiplier > 3 (premium high productive sector).

5. Conclusions and Policy Recommendations

Although gastronomic activities are common and merged into daily life for the Thai people, promoting gastronomy tourism to the flagship in terms of of refreshing the Thai economy after the COVID-19 outbreak is a difficult task in terms of political consideration and decentralized development. It is very clear that Bangkok is the most popular city and the signature for Thailand's gastronomy tourism. However, Bangkok is just a small area that can only provide short-term tourism, meaning a short trip by low-cost travelers. Consequently, this issue is what has inspired the authors to apply dynamic regional I-O analysis to clarify the unsustainable development of gastronomy tourism in Thailand. When we move our attention to regional monitoring, there are many areas in Thailand that have yet to be developed as valuable destinations of gastronomic activities.

The South of Thailand is the leader in terms of ocean-gastronomic areas. Considering the north of Thailand, this area can be defined as 'truly forest'. Many unique foods from unique tribes here are the key to refreshing the sustainability of long-term travel. The Western and Northeastern regions present a good opportunity for renewal due to the combination of local lives with local foods. Through their connectivity with neighboring countries, these two areas have potential in multi-national gastronomy tourism. The Central region is indicated as a last option, but this is an interesting region that can be promoted in terms of 'historical gastronomy activity', which can be a locally-generated source of national incomes from downstream production lines.

The conclusion of this article is that gastronomy tourism is the solution for reversing Thailand's economic depression caused by the COVID-19 pandemic. Gastronomic activities are deeply linked to the power of purchasing by domestic tourists, which is the only way to rescue local small businesses in the tourism sector. The dynamic regional I-O model is not a novel econometric application, but it can efficiently help to monitor the whole economic system with trustworthy information inputs. The recent economic sectors of tourism in Thailand, based on the structure of the tourism economy, were constructed using the 2017 tourism I-O table database. This database is officially provided by the Thailand Ministry of Tourism and Sports and serves as the main source for this paper. Assuming that the pandemic is less impactful, the results strongly suggest that Thailand's gastronomic tourism can have a positive impact on other economic sectors, particularly after the economic downturn caused by the COVID-19 pandemic. This is because gastronomic activities have an influence on both downstream and upstream production lines.

The main policy recommendation of this research study is to stimulate gastronomic tourism in several regions of Thailand through digital tourism platforms (Sigala 2020; Bekele and Raj 2024). These platforms aim to connect tourists with local gastronomic experiences, particularly in the Northeastern, Central, and Western regions of Thailand (see Tables 5 and 6). This is necessary because both regions have a lower I-O multiplier compared to other regions in Thailand. Furthermore, it is crucial for both the public and private sectors to collaborate with food bloggers, chefs, and social media influencers to create an ecosystem that promotes Thai gastronomy and covers every regional part of Thailand extensively (Gursoy and Chi 2020; Kiráľová and Malec 2021). Because of the experience of COVID-19, the significant part of policies regarding the gastronomic tourism industry for every region of Thailand must focus on health and safety protocols in order for all gastronomic tourism activities to boost demand and supply in sustainable gastronomic tourism (Baum and Hai 2020).

Moreover, the tourism industry in Thailand has grown very quickly, but there has been a lack of balance in its progress for a long time, especially in the development of gastronomy tourism. Based on data from 2019, gastronomy tourism in Thailand contributes significant income to the Thai economy. It was found that only two regions, Bangkok & Vicinities and Southern Thailand, contributed income to the Thai economy. However, this research is consistent with this report as well, because the overall multipliers of the food industry in these regions were the highest compared to other regions of Thailand (see Tables 2–6).

The second policy recommendation aims to enhance digital marketing to promote and support the distinctive aspects of gastronomy tourism in every region of Thailand, ensuring a fair distribution of economic benefits throughout the country (Thirumoorthi and Sedigheh 2021).

For future research, an updated tourism I-O table would provide a more accurate representation of the realities of gastronomic tourism in the country, which is the limitation of this study. However, the new updated tourism I-O table for Thailand will be announced soon[3], and it will be more precise in computing the multiplier of the food industry's impact on gastronomy tourism and would be more appropriate for examining its economic impact for future studies. This research article used a specific tourism I-O table from 2017, one that was recently updated in Thailand[4]. Normally, the I-O table must be surveyed to collect data every 5 years as per the standard in Thailand[5]. This is because the I-O table assumes that the economic structure changes slowly every 5 years[6].

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Notes

1. See https://www.un.org/sustainabledevelopment/sustainable-development-goals/ (accessed on 29 May 2024).
2. See https://www.unwto.org/gastronomy-wine-tourism (accessed on 29 May 2024).
3. See https://www.mots.go.th/mots_en (accessed on 29 May 2024).
4. See https://www.mots.go.th/news/category/433# (accessed on 29 May 2024).
5. See https://www.nesdc.go.th/more_news.php?cid=570&filename=io_page (accessed on 29 May 2024).
6. See https://apps.bea.gov/scb/issues/2020/12-december/1220-reprint-input-output-tables.htm (accessed on 29 May 2024).

References

Baum, Tom, and Nguyen Thi Thanh Hai. 2020. Hospitality, tourism, human rights and the impact of COVID-19. *International Journal of Contemporary Hospitality Management* 32: 2397–407. [CrossRef]

Bekele, Henok, and Sahil Raj. 2024. Digitalization and digital transformation in the tour-ism industry: A bibliometric review and research agenda. *Tourism Review*, *ahead-of-print*. [CrossRef]

Benedek, Zsófia, Imre Fertő, and Viktória Szente. 2020. The multiplier effects of food relocalization: A systematic review. *Sustainability* 12: 3524. [CrossRef]

Brankov, Jovana, Ivana Penjišević, Nina B. Ćurčić, and Branko Živanović. 2019. Tourism as a Factor of Regional Development: Community Perceptions and Potential Bank Support in the Kopaonik National Park (Serbia). *Sustainability* 11: 6507. [CrossRef]

Chaitip, Prasert, and Chukiat Chaiboonsri. 2009. Thailand's international tourism demand: The ARDL approach to cointegration. *Annals of the University of Petrosani: Economics* 9: 163–84.

Dwyer, Larry, Peter Forsyth, and Wayne Dwyer. 2010. *Tourism Economics and Policy*. Bristol: Channel View Publications.

FAO. 2020. Sustainable Food and Agriculture. Available online: https://www.fao.org/sustainability/background/en/ (accessed on 2 February 2022).

Giri, Kalpana. 2021. Initial assessment of the impact of COVID-19 on sustainable forest management: Asia-Pacific States: A case study on Thailand and Nepal. In *United Nations Forum on Forests Secretariat*. New York: United Nations. Available online: https://www.un.org/esa/forests/wp-content/uploads/2021/01/COVID-19-SFM-impact-AsiaPacific.pdf (accessed on 1 January 2022).

Gursoy, Dogan, and Christina G. Chi. 2020. Effects of COVID-19 pandemic on hospitality industry: Review of the current situations and a research agenda. *Journal of Hospitality Marketing & Management* 29: 527–29. [CrossRef]

Hardadi, Gilang, and Massimo Pizzol. 2017. Extending the multiregional input-output framework to labor-related impacts: A proof of concept. *Journal of Industrial Ecology* 21: 1536–46. [CrossRef]

Isard, Walter. 1951. Interregional and regional input-output analysis: A model of a Space-economy. *The Review of Economics and Statistics* 33: 318–28. [CrossRef]

Kiráľová, Alžbeta, and Iveta Hamarneh. 2017. Local gastronomy as a prerequisite of food tourism development in the Czech Republic. *Marketing and Management of Innovations*, 15–25. [CrossRef]

Kiráľová, Alžbeta, and Lukáš Malec. 2021. Local food as a tool of tourism development in regions. *International Journal of Tourism and Hospitality Management in the Digital Age (IJTHMDA)* 5: 54–68. [CrossRef]

Kronenberg, Kai, Matthias Fuchs, and Maria Lexhagen. 2018. A multi-period perspective on tourism's economic contribution—a regional-input-output analysis for Sweden. *Tourism Review* 73: 94–110. [CrossRef]

Liu, Juanita C., and Turgur Var. 1986. Resident attitudes toward tourism impacts in Hawaii. *Annals of Tourism Research* 13: 193–214. [CrossRef]

Miller, Ronald E., and Peter D. Blair. 2009. *Input–Output Analysis: Foundations and Extensions*, 2nd ed. New York: Cambridge University Press. [CrossRef]

Mitchell, Ross E., and Donald G. Reid. 2001. Community integration: Island tourism in Peru. *Annals of Tourism Research* 28: 113–39. [CrossRef]

Rachão, Susana, Zélia Breda, Carlos Fernandes, and Veronique Joukes. 2019. Food tourism and regional development: A systematic literature review. *European Journal of Tourism Research* 21: 33–49. [CrossRef]

Rey, Sergio J. 2000. Integrated regional econometric and input-output modeling. *Papers in Regional Science* 79: 271–92. [CrossRef]

Rinaldi, Chiara. 2017. Food and gastronomy for sustainable place development: A multidisciplinary analysis of different theoretical approaches. *Sustainability* 9: 1748. [CrossRef]
Santos, Joost R. 2005. Inoperability input-output modeling of disruptions to interdependent economic systems. *Systems Engineering* 9: 20–34. [CrossRef]
Sargento, Ana Lúcia Marto. 2009. *Regional Input-Output Tables and Models. Interregional Trade Estimation and Input-Output Modelling Based on Total Use Rectangular*. Coimbra: University of Coimbra. Available online: https://estudogeral.uc.pt/bitstream/10316/10120/3/Regional%20io%20tables%20and%20models_cd%20pdf%20file.pdf (accessed on 1 May 2020).
Sigala, Marianna. 2020. Tourism and COVID-19: Impacts and implications for advancing and resetting industry and research. *Journal of Business Research* 117: 312–21. [CrossRef] [PubMed]
Stadler, Konstantin, Richard Wood, Tatyana Bulavskaya, Carl Johan Södersten, Moana Simas, Sarah Schmidt, Arkaitz Usubiaga, José Acosta-Fernández, Jeroen Kuenen, Martin Bruckner, and et al. 2018. EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology* 22: 502–15. [CrossRef]
TAT. 2019. *Tourism Markeing Campaign*. Bangkok: TAT.
Thailand Ministry of Natural Resources and Environment. 2021. Thailand Forest Statistics 2020. Available online: http://forestinfo.forest.go.th/Content.aspx?id=10400 (accessed on 15 January 2022).
Thailand Ministry of Tourism and Sports. 2019. Tourism Statistics 2019. Available online: https://www.mots.go.th/more_news_new.php?cid=521 (accessed on 15 March 2021).
Thailand Ministry of Tourism and Sports. 2020. Tourism I-O Table. Available online: https://www.mots.go.th/more_news_new.php?cid=433 (accessed on 1 April 2021).
Thirumoorthi, Thinaranjeney, and Moghavvemi Sedigheh. 2021. Digital marketing and gastronomic tourism. In *The Routledge Handbook of Gastronomic Tourism*, 1st ed. London: Routledge, p. 9. [CrossRef]
UNESCO. 2013. *Creative Economy Report 2013 Special Edition*. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000224698 (accessed on 1 May 2024).
United Nations. 2020. Sustainable Gastronomy Day 18 June. Available online: https://www.un.org/en/observances/sustainable-gastronomy-day (accessed on 2 February 2022).
World Health Organization. 2020. The Ministry of Public Health and the World Health Organization review Thailand's COVID-19 Response. Available online: https://www.who.int/thailand/news/detail/14-10-2020-Thailand-IAR-COVID19 (accessed on 2 February 2022).
Zhang, Bo, Z. M. Chen, Li Zeng, Han Qiao, and Bin Chen. 2016. Demand-driven water withdrawals by Chinese industry: A multi-regional input-output analysis. *Frontiers of Earth Science* 10: 13–28. [CrossRef]
Zimmermann, Karl, André Schröder, and Jesko Hirschfeld. 2013. A regional dynamic input-output model of tourism development in the light of climate change. In *Beiträge zum Halleschen Input-Output-Workshop 2012. IWH-Sonderheft 1/2013*. Halle: Institut für Wirtschaftsforschung Halle.

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Water For Food in Euphrates–Tigris River

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Abstract: Water scarcity is an important threat to food security in the Euphrates–Tigris river. Water scarcity is a huge worldwide problem that results from the rapid increase in water demand, which exceeds the amount of available water. The most significant problems currently affecting countries are food insecurity water scarcity. The Euphrates–Tigris river countries suffer from different political issues, such as the Syrian war and internal civil conflicts in Iraq. In addition, this area consists of only three countries: Iraq, Syria, and Turkey, but it affects the entire Middle East. Turkey has established many irrigation projects compared to Iraq, which still suffers from the previous American invasion. Therefore, this study examines the Euphrates–Tigris river (using two countries) to examine the relationship between water scarcity and food security from 1992 to 2020. This study will be conducted using a fixed and random regression approach over 18 years. The results show a negative relationship between water scarcity and food security in the short run, at a 10% significance level, and a long-term positive relationship of 1%. Thus, the use of research and development and the encouragement of investments will help policymakers to develop a nexus between water scarcity and food security.

Keywords: water; agriculture; food; Euphrates–Tigris river; urban development; development studies

1. Introduction

Water is not only a factor of involving food, environmental challenges, and health issues, but it now plays a significant role in economic and social activities as well. Over the past decade, conflicts over shared water resources in the Middle East have peaked. The disputes over the Euphrates–Tigris river between Turkey, Syria, and Iraq threaten the stability and peace of these countries. With the construction of dams and different water development projects since the 1950s, water sharing has become a huge conflict, particularly due to a lack of a water sharing agreement or water mismanagement. This issue has become critical, specifically for downstream countries.

As the Euphrates–Tigris river benefits all countries in the region, as shown in Figure 1, Turkey claims that the local dam is beneficial to Iraq, assuming an increase in the regulated flow of the Tigris water, and Iraqi officials stated that Iraqi farmers are facing huge uncertainty regarding their agricultural crops, as they are now subject to the whims of Ankara (Zarei 2020). Moreover, Iraq was one of the few countries in the region that was considered a grain and cereal exporter in the past, and it was planning to be a grain exporter by 2017, but it has now been transformed into a grain importer, which reflects the disastrous agricultural outcome of the current water situation (Ewaid et al. 2021).

As a result of the decrease in the amount of water flowing from the Tigris and Euphrates rivers, farmland has diminished across Iraq. The country's agricultural import bill has greatly increased because many farmers in the two river basins have been unable to grow crops for years, and some have abandoned their dried fields throughout Iraq. The water levels in Iraq's major dams that feed the irrigation system have receded sharply and shockingly, as Iraq's major reservoirs are now too shallow to operate (Dillen 2019). Due to the water shortage, Iraq's Ministry of Agriculture announced to the farmers in the river basin that they would not have the ability to plant rice for the season of 2021 (Giovanis and Ozdamar 2023).

Figure 1. Tigris–Euphrates region (source: Google Maps).

The agricultural sector has huge social and economic impacts and plays a dominant role in the national life of Turkey. It accounts for approximately 10% of exports, 47% of civilian employment, and 20% of the gross domestic product (Aamir et al. 2021). Dams have played a significant role in the growth of the Turkish economy, as they have provided huge assistance in meeting the irrigation and power needs of the country. However, in 1995, Turkey emerged as a major exporter of textile products to the EU markets, which sharply increased domestic demand for cotton. This resulted in a rapid increase in the demand for cotton in the domestic market, and the increasing cotton demand outpaced domestic production; therefore, Turkey increased its cotton imports from around the world and became a cotton importer, giving Turkey seniority in the Euphrates–Tigris river countries in regards to the value of agricultural production, which increased by 90% in Turkey compared to Iraq, which only increased by 1.4%, as shown in Figure 2. This can be explained by the different wars that Iraq experienced in 1998, 2003, as well as the Syrian conflicts that ultimately affected Iraq. (Al-Muqdadi 2019) reported that cotton production increased, and in 2010, the share of Southeastern Anatolia was 60%, an increase of 52% from 1980. In 2013, Turkey exported 25.8 billion tons of textiles, approximately 2 billion more than in 2012, which is the reason for the increase in agricultural production in 2013.

Turkey has less freshwater available domestically, per person, than any other country in the world (Dillen 2019), with an average of 112.5 billion m^3 of economically exploitable freshwater annually, or 1519 m^3 per person. While Iraq is facing water shortages owing to decreasing annual flow, Turkey intends to enhance its water resources throughout the nation, specifically through the GAP project, which is particularly important for producing agricultural products and hydropower generation (Uzlu et al. 2014). Hydropower generation is another significant water use sector. Although Turkey has a gross hydropower potential of 433 billion kWh/year, only 125 billion kWh/year can be used economically

(Al-Idami and Faraj 2021). After the construction of new hydropower plants, 36% of the country's economic potential would be tapped. Electricity production reached 16.9 TWH in 2013, accounting for 28.5% of the total hydroelectric power. In 2004, it reached 22.4 TWH, accounting for 14.9% of total Turkish electricity production, which decreased by 11.8%. Therefore, an increase in the usage of water in irrigation systems was not effective in producing electricity (Uzlu et al. 2014), as shown in Figure 3.

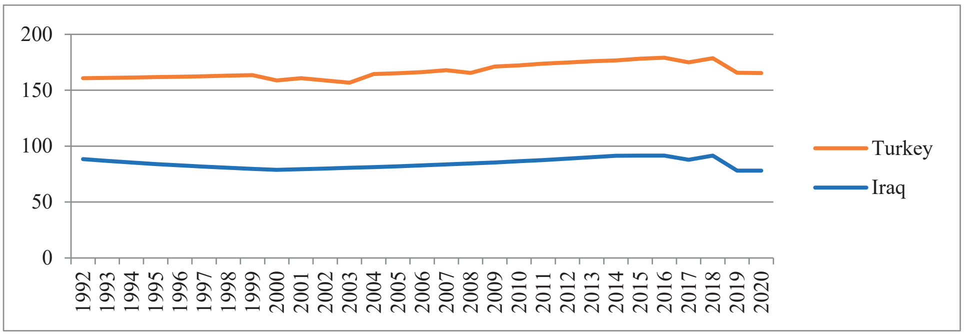

Figure 2. The value of agriculture production in Iraq and Turkey (1992–2021). Source: the authors, according to data from the Food and Agriculture Organization (FAO).

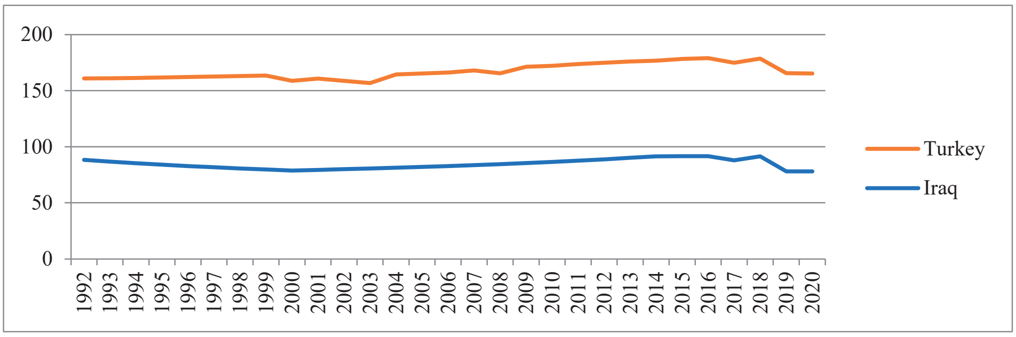

Figure 3. Created by the authors, according to annual freshwater withdrawals (agriculture) in Turkey (1992–2020). Source: World Bank data.

According to (Abd El Mooty et al. 2016), Iraq relies on the Tigris and Euphrates Rivers as the main sources of freshwater. These two rivers originate from Turkey, and they account for more than 90% of Iraq's surface water. Turkey controls the total annual flow of rivers, with 65.7 BCM from a total of 80 to 84.2 BCM of annual flow (Al-Bayaa and Mashhad 2023). Iraq's fresh water supply has decreased as a result of the dams built by both Turkey and Syria, which have a storage capacity of 14.1 BCM, and 138 BCM of water, respectively. In addition, the agricultural watering method in Iraq involves flooding the land, which has low efficiency and causes other losses of water.

The decrease in water availability has a negative impact on the agricultural sector, which accounts for 60–80% of the total water consumption, particularly in southern Iraq, where farmers rely on fresh river water for irrigation (Al-Bayaa and Mashhad 2023). However, inefficient irrigation practices, including furrow irrigation and flooding, contribute to high evaporation, runoff, and waste (Al-Muqdadi 2019). Advanced systems, such as drips systems and sprinklers, can reduce water waste, but their high cost and financing make adoption difficult. Furthermore, heavy pollution and byproducts of industrial, agricultural, and human activities along the border and domestic waterways have harmed Iraq's agricultural sector. Waterways are also contaminated because of the discharge of untreated wastewater and agricultural runoff into rivers, resulting in an increase in the prevalence of illnesses, including cancer, hepatitis, and cholera epidemics. Natural ecosystems have been adversely affected by the depletion of water supplies, pollution, and increased salinization. This has resulted in a loss of habitat, biodiversity, and agricultural livelihood in high-value cultural areas, such as Iraq's southern marshes. This study aims to demonstrate the effect of water scarcity on food security in the Euphrates–Tigris river and its effect on agricultural output.

Therefore, this paper will be divided into three main parts, with the first being the theoretical handling of the literature background. The methodology is discussed in the second part, and the results are explained in the third part. Finally, the final section comprises the Conclusion and References.

2. Literature Review

The theoretical background is made up of the connections and definitions of the topics, as they connect theories with real-life practices. The literature review consists of two parts: both theoretical and empirical.

2.1. Theoretical Literature

2.1.1. Malin Falkenmark Theory

Water accessibility is a prerequisite to habitability. The water cycle provides a nation or region with both visible and invisible water resources. The amount is governed by the country's physical location, which controls any exogenous supply imported by international rivers or aquifers from upstream nations in the same river basin, as well as the endogenous supply from rainfall across the territory. Consequently, there is a limited amount of renewable fresh water. However, this can vary significantly from year to year owing to variations in the climate. (Falkenmark et al. 1989) found that the four modes of water scarcity tend to be superimposed on each other. The first two are natural and are related to the hydroclimate. First, aridity represents a lack of moisture or precipitation, which significantly affects plant growth and agricultural productivity. Second, intermittent droughts refer to periods of limited rainfall or water scarcity that occur sporadically within a region or over a specific period, which can lead to recurrent drought years, increasing the risk of crop failure (Metwally et al. 2024). These periods can have severe impacts on agricultural productivity and food security. The remaining two factors are the result of human activity. Third, landscape desiccation is referred to as a "man-made drought" and is caused by soil deterioration that decreases local water accessibility. Fourth, water stress refers to the excessive number of people per unit of water accessible from the water cycle.

2.1.2. Marxist Theories

Marxist theories emphasize that conflicts regarding the ownership of natural resources arise between specific groups, and each group has more or less control over natural resources, such as water, and has the same interest in this resource (Sandler 1994). Scarcity can cause conflicts due to its social and negative effects, such as when freshwater and agricultural land become exhausted, which results in conflicts regarding resource shares between these groups. The Marx theory of economic development and natural resources emphasizes that the scarcity of natural resources is very dangerous for economic development. Moreover, (Zhu and Zhu 2018) have been pointed out that the utilization of natural resources in agriculture is very important from its earliest stages, and that labor productivity is connected to the quality of natural resources. Consequently, the scale of agricultural production is highly dependent on natural conditions.

2.1.3. Malthusian Theory

One of the most important theories is the Malthusian theory, which explains that war, famine, and diseases are a result of human overconsumption of natural resources that exceed the available amount, in addition to population growth (Ashraf and Oded 2008). Supply-induced scarcity theory complements Malthusian theory, which is the result of the degradation of environmental resources. As the amount of any natural resource declines owing to environmental degradation, the amount available to each person also decreases. Iraq faces water insecurity due to Turkish water imperialism, political and socioeconomic conflicts, and a decrease in water discharge from the Euphrates and Tigris rivers. Moreover (Ewaid et al. 2021) stated that the Iraqi government faces great fear due to the outcomes of restricted water flow from upstream riparian areas, with enormous effects mainly on the country's agricultural production and its dealings with food security due to drought. Among the ongoing Middle East crises, Turkey is allegedly manipulating the present regional instability to further its agenda in the crisis-ridden Middle East, especially by continuing in its ambitious plans to become a regional "water superpower" that may give it the main and primary control over the region's waters (Glass 2017). Turkey has also exploited the weak situation in Iraq and made the most of its geographical position.

First, the main aim of these projects was to prevent floods and maintain and control river flows, as population growth has caused high water needs. However, it rapidly turned into a plan for hydropower generation, giving Turkey the ability to limit its dependency on oil for energy (Giovanis and Ozdamar 2023). Ankara recently began filling the Ilisu Dam, the largest dam in the network. As a result, attention has been focused on Turkey's actions, and tension has been inflamed with neighboring countries. It is estimated that Turkey's various dam and hydropower construction projects have reduced Iraq's water supply along the two rivers by 80% since 1975, with the Ilisu Dam reducing the Tigris waters in Iraq by an additional 56% (Asaad 2023). For Iraq, the dam is likely to put greater pressure on agriculture and natural habitats, increasing desertification in regions as far away as Iraq's southern marshes.

2.2. Empirical Literature

In studying the effects of water scarcity on agricultural productivity, most studies use the terms water scarcity and water stress as synonyms. Water stress is used to measure the number of water withdrawals compared to the availability of water, whereas water scarcity refers to the pressure on water resources (Damkjaer and Taylor 2017; Doeffinger and Hall 2020; OhIsson 2000). Although there are many metrics used to study water stress, some indicators were missed owing to the use of non-renewable water, the lack of environmental flows, and alternatives to water (Wada and Bierkens 2014).

The nexus between water security and GDP was studied in the context of economic growth and agricultural value added in Gambia from 1970 to 2017 (Ceesay et al. 2021). After conducting an autoregressive distributed lag model (ARDL) in the short run and long run, along with Granger causality, a negative relationship was found between GDP growth rates and agricultural production. Climate change also plays a vital role in studying this relationship, as indicated by (Ahmed et al. 2023) using the average temperature, NO_2, methane gas emissions, CO_2 emissions, and food production from 1990 to 2019 in India using the ARDL model. This study found a positive relationship between food production and methane emissions, while the relationship between food production and other variables was negative.

In a study conducted by (Saidmamatov et al. 2023), they found a positive relationship between water, agricultural production, and GDP. This relationship was studied using the fully modified ordinary least squares regression model (FMOLS) and ARDL from 1992 to 2020 in Central Asia. This positive relationship was also observed in Pakistan from 1975 to 2017 (Soharwardi et al. 2021). This study uses variables such as the food production index, water availability, remittances, fertilizers, and the number of tractors, depending on the ARDL method.

Doeffinger and Hall (2020) reported a statistically significant relationship between freshwater withdrawal from internal resources and water productivity. The water productivity expression was used to refer to the number of yields that can be produced, which has a positive relationship with GDP. Moreover, developing countries face greater water stress than other developed countries. This study concludes that there is a negative relationship between water stress and productivity, depending on variables such as population, political stability, and agricultural lands, using OLS regression and its fixed and random effects.

By examining the relationship between water scarcity and food security (Mperejekumana et al. 2023), we tested variables such as water withdrawals, the use of energy in agricultural activities, planted area, the use of pesticides, the use of fertilizers, and annual agricultural yield in Burundi. This study concluded that there is a positive impact of all variables, including water withdrawals, on the agricultural yield per year, depending on the ARDL and ARIMA tests. Finally, the application of the ARDL model to study this relationship was conducted in 15 developing countries between 1993 and 2016, depending on variables such as GDP per capita, water withdrawals, food production index, CO_2 emissions, total population, renewable energy waste, financial aid, and foreign direct investment (FDI). (Hanif et al. 2019) concluded that all factors have a significant positive relationship with the food production index, except CO_2 and renewable wastes, which have negative impacts.

Wang et al. (2020) studied the nexus between water stress, food production, energy and CO_2 emissions, and GDP growth from 2004 to 2017 in 30 Chinese provinces. This was analyzed using the GMM model. This study found a significant positive relationship between the variables. (Ozturk 2015) studied this relationship in BRICS from 1980–2013, depending on the food index, energy use, water productivity, CO_2 emissions, health expenditure per capita, gross capital formation, and labor force participation rate. This was performed using the GMM model, showing the positive relationship between water and food production. A summary of the main empirical literature is shown in Table 1.

Table 1. Summary of the literature.

Literature	Application	Model	Expected Relationship
(Ahmed et al. 2023)	1990–2019 in India	ARDL	-
(Doeffinger and Hall 2020)	179 developing countries over different periods	OLS (fixed & Random)	-
(Mperejekumana et al. 2023)	1993–2016 Burundi	ARDL-ARIMA	+
(Ozturk 2015)	1980–2013 BRICS	GMM	+
(Wang et al. 2020)	2004–2017 in 30 provinces in China	GMM	+

Therefore, this study examines the nexus between water, energy, and food in the Euphrates–Tigris river, as no previous literature has economically evaluated the nexus in that area. Therefore, the ARDL statistical method is useful for testing the following hypotheses:

H0. *There is no relationship between water scarcity and food security.*

H1. *Water scarcity affects food security positively.*

H2. *The increase in the rate of urbanization will have a positive relationship with food security.*

H3. *The increase in GDP per capita will increase food security.*

3. Methodology

This study aimed to investigate the main aspects affecting the relationship between food security and water scarcity in the Euphrates–Tigris river. This will be done by using macroeconomic variables such as GDP per capita growth (GDP), freshwater withdrawals (WATER), total population (POP), planted land (LAND), and agriculture production (AGR). These data were obtained from the World Bank, except for the values for agricultural production, obtained from the FAO from 1992 to 2020, as explained in Table 2. These variables were logged because of the large distance between the maximum and minimum values of these data and the decrease in heterogeneity. These data were applied to the Euphrates–Tigris river countries, with evidence from Iraq and Turkey only.

Table 2. List of variables.

Variable	Symbol	Unit	Definition	Source
Gross domestic product per capita (growth rate)	GDP	%	The gross domestic product divided by the total population	World Bank
Fresh water withdrawals	Water	%	The amount of water obtained by the agricultural sector	World Bank
Value of agricultural production	AGR	$	The sum of agriculture production whatever its kind; crops, fruits, or vegetables	FAO
Total population	POP	%	Total population	World Bank
Planted land in regards to total land	LAND	%	Total amount of planted agricultural lands	World Bank

Before testing the relationship between food security and water scarcity, it was important to check the stationarity of the data. Thus, this will be done by running an augmented Dickey–Fuller test (ADF) and Phillips–Perron test. These two tests will be useful in solving the robustness and autocorrelation issues (Koondhar et al. 2021). Therefore, the proposed model is expressed in Equation (1) as follows:

$$\text{WATER} = f(\text{AGR, GDP, POP, LAND}) \quad (1)$$

The autoregressive distributed lag model (ARDL) is reliable because most of the literature depends on its analysis, and it is efficient for use in long- and short-run tests using panel data (Anderson and Hsiao 1982). One of the main advantages of the use of ARDL is the unbiased long-run results in small samples (Zhou and Li 2022). The equation applied is as follows:

$$\Delta LogAGRt = \alpha 0 + \sum \beta 1 \Delta Log\ water\ t + \sum \beta 2 \Delta LogGDPt + \sum \beta 3 \Delta Loglandt + \sum \beta 4 \Delta Logpopt + \varepsilon t \quad (2)$$

4. Results

The results of the descriptive data for the two countries (Iraq and Turkey) used by the authors in examining the relationship between food security and water scarcity in the Euphrates–Tigris Region are shown in Table 3. After logging the data to decrease the gap between the maximum and minimum, the highest mean was found for land (35.81799) compared to the lowest mean for GDP (4.215761).

Table 3. Summary of descriptive data.

	AGR	WATER	GDP	LAND	POP
Mean	16.50515	4.424127	4.215761	35.81799	17.59087
Median	16.49841	4.426913	3.691211	35.78604	17.68570
Maximum	18.14346	4.516339	49.03164	53.56210	18.22927
Minimum	14.86283	4.283150	−38.56172	18.07423	16.69731
Std. Dev.	1.291629	0.053057	11.41301	15.57054	0.491350
Observations	58	58	58	58	58

Source: authors' compilation.

The correlation matrix is estimated in Table 4 to show the significance at 1% of AGR with POP, AGR with POP, and LAND with POP. This matrix shows a negative relationship between the AGR and water, but this is insignificant. This does not reflect the fact that there are other factors that affect it in the Euphrates–Tigris river region. Thus, more tests should be performed; a unit root test was conducted to test stationarity, and the results are shown in Table 5.

Table 4. Correlation matrix.

Correlation	AGR	WATER	GDP	LAND	POP
AGR	1.000000				
WATER	−0.175341	1.000000			
GDP	−0.114417	0.055942	1.000000		
LAND	0.980232 ***	−0.229640 *	−0.103674	1.000000	
POP	0.923699 ***	−0.022379	−0.210826	0.910488 ***	1.000000

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

The results of the unit root test show that the data are stationary at the 1st difference (I1), whether using the PP or ADF test, as shown in Table 5. GDP is stationary at the level (I0) and 1st difference (I1). This means that the data are more stationary in the long run than in the short run.

Table 5. Unit root test results.

Variables	ADF		PP	
	Level	1st Difference	Level	1st Difference
		AGR		
None	1.359381	−6.771341 ***	1.239064	−6.808791 ***
Intercept	−0.707011	−6.912605 ***	−0.800432	−6.910657 ***
Intercept and trend	−1.910261	−6.856515 ***	−2.169996	−6.854374 ***
		WATER		
None	−0.078612	−4.132244 ***	−0.079009	−8.874709 ***
Intercept	−2.791689 *	−4.093315 ***	−2.641475 *	−8.804276 ***
Intercept and trend	−2.837755	−4.072185 **	−2.683552	−8.803629 ***
		GDP		
None	−7.324519 ***	−6.153025 ***	−7.340477 ***	−27.11373 ***
Intercept	−8.062800 ***	−6.224865 ***	−8.427984 ***	−29.51464 ***
Intercept and trend	−8.156119 ***	−6.506810 ***	−8.706517 ***	−36.30344 ***
		LAND		
None	0.422345	−7.350134 ***	−2.064512 **	−7.350190 ***
Intercept	−0.989429	−7.382757 ***	−0.989429	−7.382780 ***
Intercept and trend	−1.833363	−7.314182 ***	−1.877115	−7.314216 ***
		POP		
None	5.447589	−4.982327 ***	5.299877	−5.161148 ***
Intercept	−1.798575	−6.991655 ***	−1.792188	−6.991192 ***
Intercept and trend	−0.911975	−7.270856 ***	−0.943827	−7.270987 ***

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

A diagnostic test was performed to assess the functionality of the model. Table 6 shows the results of the diagnostic test to examine heteroscedasticity and correlation. The results show the significance of the absence of serial correlation and heteroscedasticity between the data.

Table 6. Diagnostic tests.

Test	t-Statistic	Result
Breusch–Godfrey serial correlation LM	84.33489 ***	No serial correlation
Ramsey test	4.113254 ***	Correct function
Breusch–Pagan–Godfrey test	5.011080 ***	No heteroskedasticity

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

CUSUM and CUSUM squared tests were also used to investigate the stability of the model in Figures 4 and 5. These two tests showed the significance of the variables, which is significant below 5%.

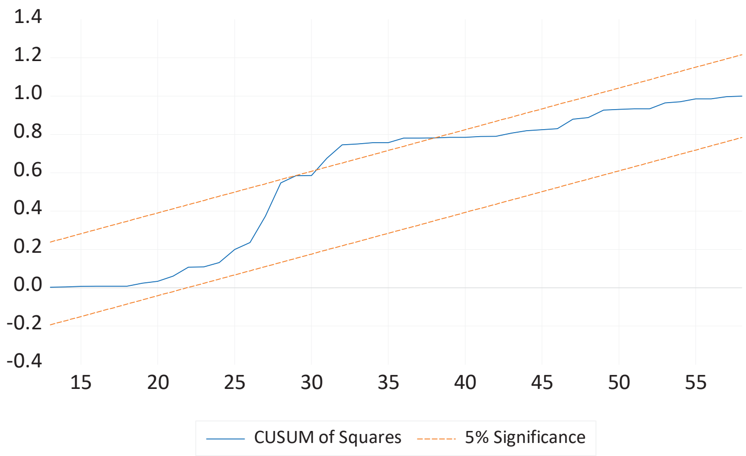

Figure 4. CUSUM squared test results.

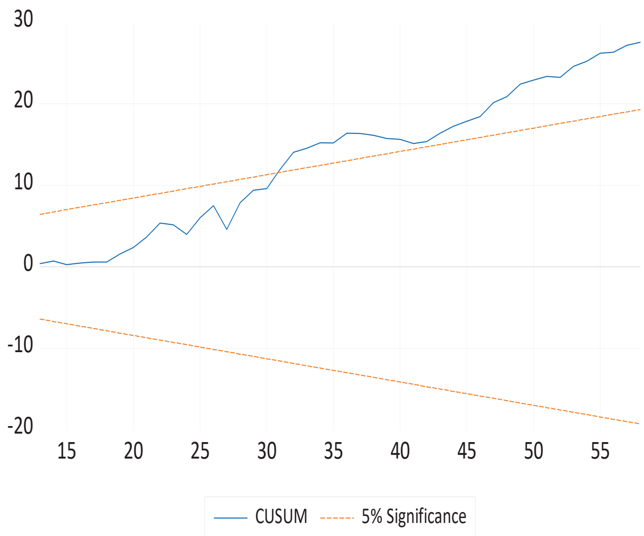

Figure 5. CUSUM test results.

Before running the ARDL test, a VAR model is used to estimate the optimal lag that the model will use. This model uses AGR as a dependent variable, whereas the other variables are independent variables. The lag length results are displayed in Table 7, which shows that all the optimal lag length criteria were accepted until the fifth lag (0, 1, 2, 3, 4, and 5). According to Schwarz (SC) and Hannan–Quinn (HQ) information criteria, the optimal lag is accepted at lag 1, whereas it is accepted for sequential modified LR (LR), final prediction error (FPE), and Akaike (AIC) test statistics at lag 5. Thus, lag 5 will be used at the AIC, which will be reliable when using the ARDL model.

Then, the ARDL test is run in Table 8, beginning with the results of the ARDL bounds and the results of the ARDL test itself. The coefficient is greater than the values of the bounds test at I(0) and I(1), which indicates the fitness of the ARDL model. ARDL was then conducted over the short and long run. In the short run, WATER and LAND at the 10% level were significant at the 1% level, except for GDP at the 5% level. Compared to the long run, the relationship was not significant for all variables, as WATER, POP, GDP, and LAND were significant at the 5% or 1% level.

Table 7. Lag length criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−299.9753	NA	0.068504	11.50850	11.69438	11.57998
1	27.46961	580.7513	7.61×10^{-7}	0.095487	1.210746 *	0.524362 *
2	50.05293	35.79245	8.55×10^{-7}	0.186682	2.231324	0.972953
3	79.90079	41.67437	7.61×10^{-7}	0.003744	2.977769	1.147410
4	106.0894	31.62392	8.31×10^{-7}	−0.041108	3.862301	1.459955
5	146.2183	40.88608 *	5.92×10^{-7} *	−0.612011 *	4.220781	1.246448

Source: authors' compilation; * significant at 1%.

Table 8. ARDL results.

Panel I: ARDL bounds			
F-statistic	Level of significance	Bound test critical values	
		I(0)	I(1)
5.164196	10%	3.03	4.06
	5%	3.47	4.57
	2.5%	3.89	5.07
	1%	4.4	5.72
Panel II: ARDL results			
short run	Coefficient	Long run	t-statistic
AGR(-1)	0.953055 ***	AGR(−1) *	−0.046945
GDP	0.002125	WATER	−1.297425 **
GDP(-1)	0.002288 **	GDP(−1)	0.004413 *
WATER	−1.297425 ***	LAND(−1)	−0.003734
POP	0.277114	POP	0.277114 **
LAND	0.055072 ***	D(GDP)	0.002125
LAND(-1)	−0.064499 ***	D(LAND)	0.055072 ***
LAND(-2)	0.005693	D(LAND(−1))	−0.005693
C	1.775286	C	1.775286

Source: author' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

Moreover, the effects of causal cointegration were evaluated for the region as a whole and for each country separately, depending on the Granger causality test, as shown in Table 9. These findings show that the relationship between food security and water scarcity is correlated in each country, but not in the whole region, as it can be expressed by the abundance of planted lands in Iraq and the dams that were established in Turkey.

Table 9. Granger causality results.

Null Hypothesis	F-Statistic	F-Statistic (Iraq)	F-Statistic (Turkey)
WATER does not Granger Cause AGR	0.90762	1.67489	1.11091
AGR does not Granger Cause WATER	1.37674	5.19937 **	4.06070 **
GDP does not Granger Cause AGR	0.79083	0.16823	0.24246
AGR does not Granger Cause GDP	0.67793	3.03053 *	0.27178
LAND does not Granger Cause AGR	1.64139	2.74314 *	0.83844
AGR does not Granger Cause LAND	0.95671	0.51805	1.83964
POP does not Granger Cause AGR	4.18893 **	0.20775	2.96132 *
AGR does not Granger Cause POP	2.32595 *	0.22651	2.27115
GDP does not Granger Cause WATER	0.11011	0.09452	1.48315
WATER does not Granger Cause GDP	0.51314	0.33689	1.60061
LAND does not Granger Cause WATER	0.68419	3.03756 *	2.00947
WATER does not Granger Cause LAND	1.35656	2.84103 *	1.28914
POP does not Granger Cause WATER	0.49777	0.04711	2.96982 *
WATER does not Granger Cause POP	0.30713	1.29988	0.23293
LAND does not Granger Cause GDP	0.07909	0.37754	0.09587
GDP does not Granger Cause LAND	1.65306	0.22632	0.02659
POP does not Granger Cause GDP	0.43081	0.87105	0.84535
GDP does not Granger Cause POP	1.29729	0.70634	0.88166
POP does not Granger Cause LAND	2.13183	21.5074 ***	1.38282
LAND does not Granger Cause POP	2.39560	0.87243	5.08094 **

Source: authors' compilation; * significant at 1%; ** significant at 5%; *** significant at 10%.

5. Discussion

This study is the first to address the relationship between water scarcity and food security in the Euphrates–Tigris river region. This evaluation achieved by applying only two out of the three countries in that region because of a lack of data for Syria. In addition to a limited number of empirical studies, this relationship has been studied worldwide. Thus, the study depends on the autoregressive distributed lag model (ARDL) that has been employed in different studies using the data offered for Iraq and Turkey by the FAO and the World Bank from 1992 to 2020.

The results estimated by the model, whether in the short or long run, were consistent with the literature review conducted in Section 1, showing that the nexus between water scarcity and food security is controlled by other factors (Ahmed et al. 2023; Doeffinger and Hall 2020; Saidmamatov et al. 2023; Wang et al. 2020). As shown in the results of our model, water scarcity is negatively significant, whether in the short or the long run, and the relationship is fixed, as it resulted in the same coefficient in both runs, as concluded by (Ahmed et al. 2023; Doeffinger and Hall 2020).

Therefore, this study aimed to examine the relationship between water scarcity and food insecurity in the Euphrates–Tigris river countries from 1993 to 2020. Unfortunately, the study was limited to only two out of the three countries because of the lack of transparency of data for Syria. This study concludes that there is a clear negative relationship between water scarcity and food security, as the increase in demand for food puts a significant burden on the use of water, which has led to huge demand for water. Second, there is a significant positive relationship between the agricultural production value from one side and GDP, population, and the amount of planted land from the other side. These results were significant at the 1% level for the value of agricultural products, water, and planted land in the short run, while in the long run, only land was significant at the 1% level.

In the short run, the independent variable, that is, the value of agricultural products, was significant with D(land-2) and population and GDP per capita annual growth rate. Although an increase in GDP by 1% caused an increase in the value of agricultural products by 0.2%, a 1% increase in planted land caused a decrease in the value of agricultural production by 6.4%. This was clarified by (Mperejekumana et al. 2023), who determined that the negative relationship was due to the increase in pesticides and insecticides.

In the long run, the value of agricultural production is significant at the 1% level for planted land, at the 5% level for water and population, and at the 10% level for GDP per capita growth rate. There is a positive relationship between the value of agricultural production, GDP per capita growth rate, and planted land. If there is a 1% increase in the value of agricultural production, the GDP per capita will increase by 0.4% and 0.5% for planted land. The results are summarized in Table 10.

Table 10. Summary of results.

Hypotheses	Results in Short Run	Results in Long Run	Accept or Refuse
H0. There is no relationship between water scarcity and food security.	Negative insignificant	Negative significant	Refuse
H1. Water scarcity affects the food security positively.	Negative	Negative	Accept
H2. The increase in the rate of urbanization will have a positive relationship with food security.	Positive insignificant	Positive significant	Partially accepted, only in the long run
H3. The increase in GDP per capita will increase food security.	Positive significant	Positive significant	Accept
H4. The increase in planted land will increase food security.	negative significant	positive significant	Partially accepted, only in the long run

6. Conclusions

Ultimately, the water resources between countries have always been a source of conflict and negotiation. As the condition of the Euphrates–Tigris river system has increased water scarcity and insecurity, determining a water management plan between Turkey, Iraq, and Syria has remained a source of tension. The water insecurity caused by huge water development projects, specifically those initiated by Turkey, have impacted the agricultural sector in Iraq by a huge percentage. There are currently no official agreements to support and obtain fairly shared water resources among these countries, which could lead to progressively increasing fragility in terms of water resources, especially in Iraq. In addition, it was concluded that water shortages in the basin would enhance and support Turkey's economic and political control and leverage over Iraq. In conclusion, this study discusses the effects of GDP, population growth, PHDI, and annual freshwater withdrawals on the agricultural resources of both Turkey and Iraq.

This study showed the effect of water development projects on decreasing the flow of water for downstream countries, as well as the increase in Turkey's production and the initiation of irrigation and hydroelectricity projects. The results also showed that there is a significant positive relationship between the agriculture production (dependent variable) and the annual freshwater withdrawals (independent variable), so we rejected H0. Therefore there are some policy implications that should be adopted, as follows:

First, there is a need for research and development (R&D) to help increase opportunities for food consumption and decrease the amount of water required. In addition, this implies the need for more investments to connect the knowledge that individuals can acquire and the information available to them.

Second, there is a need for an increase in the usage of sewage water reuse after purifying, besides desalination, that will positively accept the use of water for activities other than food production.

Third, the countries in the Euphrates–Tigris river depend heavily on the public sector; thus, public–private partnerships should be introduced and developed in the fields of irrigation, energy, and food.

Fourth, more attention should be paid to individuals and human capital, as the Euphrates–Tigris river countries are characterized by a high population rate. Therefore, the development of educational systems and training, besides providing awareness campaigns regarding the importance of water, would be beneficial.

Fifth, to increase efficiency in the use of water, taxes and decreased subsidies should be imposed on those who are irrational in the usage of water.

Sixth and finally, as water is characterized by its inelastic supply, with no available substitutes (Markantonis et al. 2019), harsh legislation should be instituted against those who rationalize the use of water, in addition to imposing high penalties on them.

For further studies on the water–food nexus in Euphrates–Tigris river countries, greater attention should be focused on the area as a whole, including Syria, which appears to be an obstacle due to a lack of data for this country.

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Abbreviations

ADF	augmented Dickey–Fuller test
ARDL	autoregressive distributed lag
CUSUM	cumulative sum of recursive residuals
FMOLS	fully modified ordinary least squares regression
GDP	gross domestic product
PP	Pearson—Perron unit root test
VAR	vector autoregression

References

Aamir, Samreen Bari, Muhammad Mustafa Raza, and Shumaila Kamal Khan. 2021. Water Crisis between Turkey, Syria and Iraq and Its Implications. *Pakistan Journal of International Affairs* 4: 564–79.

Abd El Mooty, Mohamed, Rawya Kansoh, and Ahmed Abdulhadi. 2016. Challenges of Water Resources in Iraq. *Journal of Waste Water Treatment & Analysis* 7: 4. [CrossRef]

Ahmed, Mansoor, Jing Shuai, and Hussain Ali. 2023. The Effects of climate change on food production in India: Evidence from the ARDL model. *Environment, Development and Sustainability* 25. [CrossRef]

Al-Bayaa, Ali, and Mostafa Mashhad. 2023. Water Scarcity and Environmental Peacebuilding: A Lens on Southern Iraq. *E-International Relations*, 1–3. Available online: https://www.e-ir.info/pdf/101463 (accessed on 25 February 2024).

Al-Idami, Rahman Rabat, and Zainab Faraj. 2021. Geographical potential for hydropower investment in Iraq. *Al-Qadisiyah Journal For Humanities Sciences* 24: 322–54. Available online: https://journalart.qu.edu.iq/index.php/QJHS/article/view/452 (accessed on 15 January 2024).

Al-Muqdadi, Sameh W. H. 2019. Developing Strategy for Water Conflict Management and Transformation at Euphrates–Tigris Basin. *Water* 11: 2037. [CrossRef]

Anderson, Theodore Wilbur, and Cheng Hsiao. 1982. Formulation and estimation of dynamic models using panel data. *Journal of Econometrics* 18: 47–82. [CrossRef]

Asaad, Sangar Samad. 2023. Transboundary River Basin Euphrates-Tigris: International Legal Regulation. *Russian Law Journal* 11: 34–39. [CrossRef]

Ashraf, Quamrul, and Galor Oded. 2008. Malthusian Population Dynamics: Theory and Evidence. Available online: https://economics.brown.edu/sites/default/files/papers/2008-6_paper.pdf (accessed on 30 January 2024).

Ceesay, Ebrima K., Phillips C. Francis, Sama Jawneh, Matarr Njie, Christopher Belford, and Momodou Mustapha Fanneh. 2021. Climate change, growth in agriculture value-added, food availability and economic growth nexus in the Gambia: A granger Causality and ARDL modeling approach. *SN Business & Economics* 1: 100. [CrossRef]

Damkjaer, Simon, and Richard Taylor. 2017. The measurement of water scarcity: Defining a meaningful indicator. *Ambio* 46: 513–31. [CrossRef]

Dillen, Connor. 2019. Turkey's Dam-Building Program Could Generate Fresh Conflict in the Middle East. proQuest. Available online: https://www.proquest.com/blogs-podcasts-websites/turkey-s-dam-building-program-could-generate/docview/2311805689/se-2 (accessed on 3 February 2024).

Doeffinger, Tess, and Jim W. Hall. 2020. Water Stress and Productivity: An Empirical Analysis of Trends and Drivers. *Water Resources Research* 56: e2019WR025925. [CrossRef]

Ewaid, Salam Hussein, Salwan Ali Abed, Ali Chabuk, and Nadhir Al-Ansari. 2021. Water Footprint of Rice in Iraq. *IOP Conference Series: Earth and Environmental Science* 722: 012008. [CrossRef]

Falkenmark, Malin, Jan Lundqvist, and Carl Widstrand. 1989. Macro-scale water scarcity requires micro-scale approaches: Aspects of Vulnerability in semi-arid development. *Natural Resources Forum* 13: 258–67. [CrossRef] [PubMed]

Giovanis, Eleftherios, and Oznur Ozdamar. 2023. The Transboundary Effects of Climate Change and Global Adaptation: The Case of the Euphrates-Tigris Water Basin in Turkey and Iraq. *SSRN Electronic Journal*. [CrossRef]

Glass, Samantha. 2017. Twisting the Tap: Water Scarcity and Conflict in the Euphrates–Tigris river Basin. Independent Study Projet Collection. Available online: https://digitalcollections.sit.edu/isp_collection/2594 (accessed on 2 February 2024).

Hanif, Nighat, Madeeha Nisa, and Yaseen Muhammad Rizwan. 2019. Relationship between Food Security, Macroeconomic Variables and Environment: Evidences from Developing Countries. *Journal of Applied Economics and Business Research* 9: 27–37.

Koondhar, Mansoor Ahmed, Noshaba Aziz, Zhixiong Tan, Shaoxiong Yang, Kashif Raza Abbasi, and Rong Kong. 2021. Green growth of cereal food production under the constraints of agricultural carbon emissions: A new insights from ARDL and VECM models. *Sustainable Energy Technologies and Assessments* 47: 101452. [CrossRef]

Markantonis, Vasileios, Arnaud Reynaud, Armagan Karabulut, Rana El Hajj, Dogan Altinbilek, Ibrahim M. Awad, Adriana Bruggeman, Vangelis Constantianos, Jaroslav Mysiak, Nicola Lamaddalena, and et al. 2019. Can the Implementation of the Water-Energy-Food Nexus Support Economic Growth in the Mediterranean Region? The Current Status and the Way Forward. *Frontiers in Environmental Science* 7: 84. [CrossRef]

Metwally, Abdelmoneim B. M., Shahd M. Nabil, and Mai M. Yasser. 2024. Hydropower & HDI Nexus in Nordic Countries Using VAR Techniques. *Economies* 12: 60. [CrossRef]

Mperejekumana, Philbert, Lei Shen, Shuai Zhong, Fabien Muhirwa, Assa Nsabiyeze, Jean Marie Vianney Nsigayehe, and Anathalie Nyirarwasa. 2023. Assessing the Capacity of the Water–Energy–Food Nexus in Enhancing Sustainable Agriculture and Food Security in Burundi. *Sustainability* 15: 14117. [CrossRef]

OhIsson, L. 2000. Water conflicts and social resource scarcity. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere* 25: 213–20. [CrossRef]

Ozturk, Ilhan. 2015. Sustainability in the food-energy-water nexus: Evidence from BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries. *Energy* 93: 999–1010. [CrossRef]

Saidmamatov, Olimjon, Nicolas Tetreault, Dilmurad Bekjanov, Elbek Khodjaniyazov, Ergash Ibadullaev, Yuldoshboy Sobirov, and Lugas Raka Adrianto. 2023. The Nexus between Agriculture, Water, Energy and Environmental Degradation in Central Asia—Empirical Evidence Using Panel Data Models. *Energies* 16: 3206. [CrossRef]

Sandler, Blair. 1994. Grow or Die: Marxist Theories of Capitalism and the Environment. *Rethinking Marxism* 7: 38–57. [CrossRef]

Soharwardi, Mariam A., Abida Firdous, and Asma Sajjad. 2021. Impact of water crisis on food production in Pakistan: A time-series analysis. *International Journal of Agricultural Extension* 9: 429–37. [CrossRef]

Uzlu, Ergun, Murat Kankal, Adem Akpınar, and Tayfun Dede. 2014. Estimates of energy consumption in Turkey using neural networks with the teaching–learning-based optimization algorithm. *Energy* 75: 295–303. [CrossRef]

Wada, Yoshihide, and Marc F. P. Bierkens. 2014. Sustainability of global water use: Past reconstruction and future projections. *Environmental Research Letters* 9: 104003. [CrossRef]

Wang, Jingyi, Xiucheng Dong, Hui Qiao, and Kangyin Dong. 2020. Impact assessment of agriculture, energy and water on CO_2 emissions in China: Untangling the differences between major and non-major grain-producing areas. *Applied Economics* 52: 6482–97. [CrossRef]

Zarei, Mohanna. 2020. The water-energy-food nexus: A holistic approach for resource security in Iran, Iraq, and Turkey. *Water-Energy Nexus* 3: 81–94. [CrossRef]

Zhou, Mingxiang, and Xing Li. 2022. Influence of green finance and renewable energy resources over the sustainable development goal of clean energy in China. *Resources Policy* 78: 102816. [CrossRef]

Zhu, Jiefang, and Jiefang Zhu. 2018. Marx's Theory of Natural Resources and Economic Development. *Asian Agricultural Research* 10: 37–55. [CrossRef]

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