Evaluation of Urban Spatial Growth Performance from the Perspective of a Polycentric City: A Case Study of Hangzhou

Liang Zhang 1, Linlin Zhang 2,* and Xue Liu 3

1 College of Urban Construction, Zhejiang Shuren University, Hangzhou 310015, China; zhangliang@zjsru.edu.cn
2 Law School, Zhejiang University City College, Hangzhou 310015, China
3 School of Geographic Sciences, East China Normal University, Shanghai 200241, China; liuxue@geo.ecnu.edu.cn
* Correspondence: zhangll@zucc.edu.cn

Abstract: Although polycentrism is widely promoted by city planners and policymakers as a potential solution for alleviating the sprawl of central urban areas, there is no sufficient empirical evidence to verify the validity of this claim. Our study aims to complement this experience by providing solid evidence on whether polycentric urban structures can mitigate the problem of urban sprawl. In this study, the corresponding evaluation factors are selected from four perspectives: socioeconomic, spatial form and organization, and ecological environment, to measure the performance of Hangzhou’s polycentric spatial development. The results show that the performance in Hangzhou has improved significantly, and the performance improvement is more prominent over the 2010–2020 period. Third, the changing characteristics of the spatial development performance of the city centers show a significant diversity. During the study period, the development of Jiangnan city started early, but the development performance of Xiasha city improved significantly, and the development of Linping city was relatively the weakest. Fourth, socioeconomic and urban spatial organization are the main factors causing the temporal stage and spatial variability of the performance in Hangzhou. It can be seen that market-driven endogenous factors are more conducive to improving spatial development performance than government-led exogenous factors.

Keywords: spatial performance; polycentric structure; polycentricity; Hangzhou

1. Introduction

The rapid growth of cities has become an unstoppable trend. On the one hand, cities show more obvious agglomeration, scale, and external benefits due to their better economic structure, higher technological level, and more mature market development [1]. On the other hand, a more developed economy leads to more investment in infrastructure, more jobs, and more residential amenities, which in turn drives more people to converge in cities. Along with the rapid urbanization process in China, many large cities are facing a series of changes such as population influx, scale expansion, industrial structure adjustment, and land-use type transformation. China’s urban construction has mostly developed along the original urban roads, and the monocentric urban spatial structure has resulted in the sprawling expansion of cities to the surrounding areas in a “concentric circle” pattern, which has also led to the concentration of population in urban centers, traffic congestion, intermingled urban functions, and increasingly serious environmental pollution. To overcome the drawbacks of monocentric urban development, scholars and planners have turned to polycentricity, which is believed to eliminate regional disparities and produce more balanced territorial development [2–4]. Driven by a growing number of urban planners and policymakers [5], cities in China, such as Beijing, Shanghai, Guangzhou, and Tianjin have begun to experiment with “polycentricity” as a central goal of their spatial development strategies. Cities have gradually moved from the traditional monocentric sprawl to a
polycentric spatial layout model in order to seek urban spatial regrouping, decentralize the population and industries in the central city, and alleviate the “bloating” problem in the urban centers. However, after the implementation of the polycentric strategies, the separation of jobs and residences, long-distance commuting, and congestion in the central city are still obvious. Some large cities separated by large rivers and having the ideal layout of “polycentric, cluster-type” morphology have the same centripetal congestion as “sprawling” cities [6]. This has led to questions about the effectiveness of the “polycentric” planning strategy. Indeed, this hypothesized relationship between polycentric urban spatial structure and reduced regional disparities lacks sufficient empirical evidence to support the validity and reliability of polycentric growth [7]. Similarly, few empirical studies support the validity of such polycentric-oriented development in China.

The main objective of this paper is to assess the performance of polycentric space formation. Our study contributes to at least two important aspects. First, we test the spatial performance of cities after the implementation of polycentric structures by establishing a multidimensional evaluation system. This paper adds to the empirical research by providing reliable evidence of the effectiveness of polycentric spatial development strategies. Second, this paper provides further evidence to elucidate the main factors affecting spatial performance. By exploring the evaluation of performance in the spatial evolution of polycentric cities in China, we can rationalize the allocation of intracity elements with effective planning interventions, guide the benign evolution of cities towards compact forms, and provide a reference for decision-making to enhance the efficiency of urban spatial organization and explore the best evolutionary approach for urban spatial growth.

The paper is structured as follows: the next section reviews the development of polycentricity in China and abroad, the main studies on urban spatial performance evaluation, and the results of previous empirical studies. This is followed by a discussion of the data, models, and estimation strategies in Section 3, after which our empirical results are presented in Section 4. The fifth section explores the factors and possible causes we found to influence the spatial performance of polycentricity, and finally summarizes the results and draws conclusions.

2. Literature Review

2.1. Polycentric Spatial Development

The concept of polycentricity can be traced back to the early days of modern urban planning [8,9]. The “regional city” was proposed by Mumford (1961) who was also an advocate of the polycentric spatial development model [10]. The polycentric concept was widely researched and used after the 1980s when Hall (1984) considered the Randstad area as a polycentric metropolitan area in his book “World Cities” [11]. As we can see, the American urban planner Saarinen (1943) proposed a theory of organic decentralization to address the problem of urban overconcentration by decentralizing highly dense cities into multiple centers [12], and Harris and Ullman (1945) proposed a “multicore model” of urban structure in which, in addition to the primary economic cell (CBD), there are secondary economic cells scattered throughout the system that perform various urban functions of different levels and functions [13], as well as the decentralized city hypothesis, Friedmann, Miller (1965) and Pred (1977) on urban municipalities, these theories all embody the idea of polycentricity [14,15].

The polycentric spatial development pattern is proposed along with deepening urbanization development [16] which is the process of spatial growth of urban land scale at the macro-level and the process of conversion of different types of agricultural land into urban building land at the microlevel. An increasing number of scholars support polycentric structures, and they argue the trend of polycentric structures from different perspectives [17–24]. Polycentricity at the large city or regional level takes many different forms [25]. Dominating this particular problem are eight European megacity regions, all of which exhibit polycentric characteristics but differ significantly in terms of spatial morphology. For example, the Netherlands Randstad, a metropolitan region with a balanced
spatial distribution of roughly equal-sized cities, the German Rhineland Ruhr region, the metropolitan extension of northern Switzerland, the Paris region, the Greater Dublin region, and the southeastern England region with multiple small-scale centers around a larger urban town cluster form, and the German Rhineland Main region and the central Belgium region with both characteristics [26]. These three layouts can be seen as three stages of development in terms of dynamic development, with the more primary state being a spatially balanced distribution of cities of similar size, and the more advanced state being an urban agglomeration surrounded by smaller centers or a combination of characteristics between these two stages of development [27].

The spatial development patterns of large cities evolved from different developmental origins, with their own path-dependent trajectories, and were shaped over time by a combination of structural drivers and emergent factors [25,28]. Champion (2001) summarizes three typical polycentric development patterns from the perspective of urban spatial evolution: centrifugal, combinatorial, and convergent [29]. The centrifugal pattern is characterized by severe constraints on the sustained growth of monocentric cities, with some highly affected production and service activities forced to move to other centers. After a certain point of development, these centers may combine or even compete with the original center in terms of size on their own. The combination model refers to large urban centers that open up their own hinterlands in order to integrate with smaller, mostly self-sufficient surrounding centers in terms of employment and services. These centers may be more powerful in attracting other non-residential activities than centrifugal centers and may pose a stronger challenge to the original major centers. The convergence model refers to the “integration” of multiple, previously separate, similarly sized centers that have grown in population size and geographic scope, particularly through improved transportation links [26]. These three patterns are reflected in the spatial development of six metropolitan areas in the United States. For example, polycentric development has been further enhanced by centrifugation in Los Angeles and San Francisco. Decentralization has been dominant in Portland and Philadelphia, while Boston and New York, areas with strong, historic CBDs, have developed around strong cores of convergence. At the same time, these patterns also correspond to the spatial layout of the eight European megacity regions.

With the continuous research on polycentric cities [11,29–34], the concept of polycentric development has been increasingly explored and practiced in Chinese cities. In terms of theoretical studies, Luo and Zhu (2008) elaborated on the complete connotation of the polycentric concept from three levels: spatial form, function, and governance [8]. A theoretical model is formed from two aspects: polycentric morphological structure and measurement of urban spatial polycentricity. Shen and other scholars (2005) proposed that the spatial reorganization of “polycentric” Chinese large cities should construct a polycentric organic structure at multiple levels [35]. Zhou (2008) argues that polycentric urban spatial structures are typically characterized by point-axis and decentralized clusters [36]. Wei and Zhao (2006), based on the differences in spatial location and spatial distribution of population, outlined polycentric as four types of structures—loose, suburbanized, highly uneven, and sprawling compact polycentric structures [37]. Zhou (2007) summarized it as circle structure, belt structure, radial structure, multinuclear network structure, and main city–satellite city structure [38].

Comparing the formation of polycentric spatial structure, we can see that large cities in Europe and the United States have gone through a long development process, and the polycentric structure has gradually evolved after the phenomenon of suburbanization and sprawl of cities and then in the process of spatial expansion, which is the trend of spontaneous formation of cities at a certain stage of development. It is a spatially differentiated pattern of polycentricity depending on the development stage of the city itself. Relatively speaking, Chinese cities are in the process of rapid urbanization and development, and the polycentric structure is passively formed by planners and managers pushing to solve urban problems. Thus, the study of spatial performance evaluation has an important role in answering the applicability of polycentricity in China.
2.2. Quantitative Assessment of SPATIAL Performance

Traditional performance assessment generally focuses on the geographic description of spatial distribution, represented by theoretical models of population density distribution, such as the Clark model [39], Newing model, polycentric model, etc., which attempt to use the average population density of built-up areas, the gradient of density profiles, “rank-scale” and daily travel patterns, reflecting the efficiency of spatial pattern formation [2,34,40,41].

Chinese scholars have focused more on the study of the relationship between spatial efficiency and economic benefits. For example, the gravity model or potential model is used to simulate the strength of linkages between cities [42]; the enterprise organization network of the high-end productive service industry is used to construct the linkages between cities [43,44]. Many scholars have also analyzed the relationship between polycentric structure and urban transportation efficiency, using urban transportation as a wedge [37,45–49]. Since then, with the widespread implementation of polycentric development in China, the depth and breadth of research on urban spatial performance in China have been expanding [5,22,50,51]. In terms of assessment methods, domestic studies have generally constructed evaluation index systems from two perspectives: macro and micro. The macro perspective is built around the urban socioeconomic, ecological environment, transportation network, and the corresponding indicators are selected for the research objects; the micro perspective applies specific methods to empirical studies on the economy, infrastructure services, ecological environment, and urban transportation. In an overview of the evaluation system research about spatial performance, dimensions are basically covered: social, economic, environmental, spatial, and institutional. And the indicators are selected from relevant fields such as social economy, resources and environment, spatial form structure, and service settings.

In summary, research on the evaluation of urban spatial performance in China is at the stage of methodological exploration, and the relevant research results are relatively independent of each other, often discussing a single dimension within the city. The methods mostly use GIS analysis and economic models. The evaluation system of urban spatial performance under a macroscopic perspective selects specific indicators for different evaluation objects, there are very few empirical studies, and the universality of indicators is worth further verification; Studies under a microscopic perspective have reached a certain depth in their respective research fields and have achieved certain results. However, urban spatial structure is a complex giant system with intricate and complicated components and elements, and the evaluation of urban spatial performance under a single dimension is insufficient to describe the overall level of spatial performance.

2.3. Findings of Previous Empirical Studies

Polycentric development is considered by domestic and foreign scholars as both decentralization and agglomeration [52]. Theoretical models of urban spatial equilibrium from different perspectives such as population and consumption indicate that polycentric structure is the optimal choice for the equilibrium of the urban spatial structure. However, in terms of domestic and foreign practice, there is a lack of empirical evidence to support the validity and reliability of polycentric development. Studies of European cities by foreign scholars show significant or inverse correlations between polycentric patterns and regional differences, generally agree that higher polycentricity scores may be associated with significant gaps in domestic GDP per capita, and strongly believe that polycentric development cannot be considered a tool to reduce regional disparities [53,54]. Chinese scholars assessing polycentric development and its impact on cities have mostly focused on transportation or economic dimensions [19,48,55] and have studied the formation, evolution, and development of urban spatial structure in a performance-based manner. However, such studies have generally failed to verify the mitigation effect of polycentricity on the original urban problems. Some scholars have even proposed the opposite conclusion that monocentric is more beneficial to the development of Chinese cities in terms of the
labor force as well as economic development [50,56]. In addition, polycentric measurement studies have found that the urban polycentric spatial form is easier to accomplish, but the decentralization and balance of functions are often more difficult to achieve, resulting in a single function of subcenters and a lack of functional links between the main and secondary cities. This problem also creates a debate on the applicability of polycentric spatial structures in China.

Developed cities in Europe and America have gone through a long development process and are more mature while China’s urbanization process is slower than theirs, and the polycentric urban spatial structure has its own unique and complex growth environment, with significant differences in the development background, growth mechanism, and evolution path. Factors such as urban transformation, urbanization stage, and administrative district economy all make the process of urban spatial structure reconstruction unique in conducting polycentric spatial performance evaluation. It is urgent to construct a spatial performance evaluation system for the characteristics of China’s polycentric cities in a targeted manner. The spatial benefits generated by the ecology, economy, policies, and land use of polycentric city space are quantified by means of performance, and corresponding spatial policies are proposed. Since urban space itself has multiple attributes such as social, economic, ecological, political, and physical forms, it is obviously biased to cognize spatial performance issues from one side, and spatial performance covers both the dynamic effects presented in the process of continuous changes in urban spatial structure and the static effects produced by this change in the city at a certain moment. Therefore, the evaluation of the spatial performance of polycentric cities requires a comprehensive evaluation from a dynamic perspective and an integrated perspective.

3. Data and Methodology
3.1. The Study Area

The city of Hangzhou, whose urban polycentric structure formation is representative and researchable, was selected as the case study area for this research. Hangzhou entered a rapid urbanization stage under the reform of land policy and the tax sharing system. The urban framework initially centered on Zhongshan Middle Road and Hefang Street area in the shape of a cluster, and later radiated along the traffic routes. To solve the limitation of development space by topography and landscape, the development gradually spread along the edge of the original built-up area under the adjustment of the administrative division. With the rise of development zone construction, a local “enclave-type” spatial structure was formed; after 2000, with the cooperation of several rounds of urban planning revision, the polycentric structure as “one main, three vice (Jiangnan-Xiasha-Linping), six clusters (Tangqi-Liangzhu-Yuhang-Yipeng-Gua Li-Linpu)” was formed. The spatial pattern changes significantly in the process of rapid urbanization.

The study area covers eight administrative districts of Shangcheng, Xiacheng, Gongshu, Xihu, Jianggan, Binjiang, Yuhang, and Xiaoshan, totaling 3068 km². To better compare the spatial evolution of cities after the determination of polycentric goals, the study used the eight-district division scheme before the change in the administrative division of Hangzhou in 2021, and the two districts of Fuyang and Lin’an, which were incorporated into urban areas in 2014 and 2017, are not included. Overall, the study area is a cross-river, along-river, networked cluster layout with the Qiantang River as the axis. The main city consists of Shangcheng, Xiacheng, Xihu, Gongshu, and the western part of Jianggan district, which is the core part of the layout structure of “one main, three vice, and six clusters”; the northeast of the main city and the Linping subcity are separated by Chaoshan-Half Mountain-Gaoting Mountain-Huanghe Mountain scenic area. The northeast of the main city is separated from the Linping subcity by the Chaoshan-Banshan Mountain-Gaoting Mountain-Huanghe Mountain scenic area. The east is separated from the Xiasha subcity by ecological green areas, and the south is separated from the Jiangnan subcity by the river. Jiangnan city is composed of Binjiang district, Xiaoshan core area, and Jiangnan riverside area; Linping city is composed of Linping core area and Canal Town; Xiasha city is composed of Xiasha,
Jiubao, and Qiaosi. The peripheral group is divided into the northern and southern pieces, the northern piece consists of the Tangqi, Liangzhu, and Yuhang groups, and the southern piece consists of the Yipong, Guali, and Linpu groups (Figure 1).

**Figure 1.** Overview of the study area.

### 3.2. Model and Estimation Strategy

Urban spatial performance refers to the comprehensive effectiveness or effect of urban space [57]. The spatial performance evaluation of polycentric cities is to assess the ability to achieve performance goals and support the process of such behavior and change the dynamics of state operation through the feedback of results, thus achieving optimal adjustment of performance [58]. The performance objectives of polycentric development are to solve the problem of “expansion” of the central city and meet the development needs of various functions of the city, reasonably allocate various spatial resources, and promote the balanced development of various elements. Therefore, the study evaluates four dimensions: socioeconomic, spatial form and organization, and ecological quality. The socioeconomic dimension considers the impact of polycentric development on population evacuation and economic activity; urban spatial morphology is the territorial spatial projection of urban entities [59]. Changes in urban morphology can directly affect important issues such as the structure within the city, the connection between the city and the surrounding area, and the direction and trend of urban development [60]. The spatial morphology dimension focuses on spatial compactness, a more compact urban morphology structure can improve the efficiency of access, lower carbon, and environmental protection, and improve the liveability of the city. The spatial organization dimension considers the spatial allocation of land balance, transportation, and public facilities to reflect the alleviation of overcrowding or inefficient use of urban space, and to characterize the level of urban construction and functional mix. The ecological quality dimension considers the positive effects of polycentric development on ecological safety and low-carbon environmental protection, as well as the degree of mitigation of the urban heat island effect.

Based on the research dimension and hierarchical framework, the evaluation index system combines the specific characteristics of the spatial performance of polycentric cities
and the research purpose, adds some typical indicators to make the interpretation of spatial performance more reasonable and comprehensive, and simultaneously considers the feasibility of the research and the availability of data to build an operational evaluation system for the characteristics of indicators at each level. Each spatial dimension corresponds to the main factors describing its characteristics, and the indicators obtained can be calculated for specific analysis and evaluation, which finally forms the urban spatial performance evaluation index system (Table 1).

Table 1. The spatial performance evaluation system.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Indicators</th>
<th>Indicator Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socioeconomic</td>
<td>Population density, Rate of population change</td>
<td>• The population density is the ratio of street population to street area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The rate of population change is the ratio of the amount of population growth in a given period to the population in the base period.</td>
</tr>
<tr>
<td></td>
<td>Rate of GDP change</td>
<td>• The rate of GDP change is the ratio of the amount of GDP growth over a certain period to the GDP of the base period.</td>
</tr>
<tr>
<td>Spatial morphological</td>
<td>Urban land compactness index CI, Urban spatial compactness indexes CR1, CR2</td>
<td>• CI reflects the compactness of the spatial pattern of land use in terms of the area and perimeter of construction land plots.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CR1 measures the degree of spatial circularity using the area and perimeter of urban built-up areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CR2 measures the spatial characteristics of axial expansion using the ratio of the area of urban built-up area to its minimum external circular area.</td>
</tr>
<tr>
<td>Spatial organization</td>
<td>Equilibrium degree of the land use</td>
<td>• Calculate the entropy of land-use structure by using the proportion of the area of each land-use type to reflect the degree of order of regional land use in a certain period, and then calculate the equilibrium degree of the land use.</td>
</tr>
<tr>
<td></td>
<td>Traffic network density</td>
<td>• Line density analysis of urban arterial roads to measure the accessibility of different regions.</td>
</tr>
<tr>
<td></td>
<td>Public service facility density</td>
<td>• Extracting public service points for nuclear density analysis to reflect the accessibility in different regions.</td>
</tr>
<tr>
<td>Ecological quality</td>
<td>Remotely sensed ecological indicator (RSEI)</td>
<td>• Obtain normalized vegetation index, soil moisture, surface temperature, and normalized soil difference index based on remote sensing images to measure urban ecological quality.</td>
</tr>
</tbody>
</table>

3.3. Measure of Polycentric Performance
3.3.1. Socioeconomic Dimension

This dimension is considered to be evaluated in terms of both population and GDP. Polycentric spatial development assumes a role in China’s cities to decongest the population and balanced regional development. Population density and change in different regions are the primary indicators to be selected, and GDP reflects both the level of economic activity in different regions and the spatial distribution of employment in cities. The spatial concentration and dispersion of urban occupational and residential functions under
polycentric spatial development are measured by the changes in population and GDP. Population density analysis was performed using the census data of the study area in 2000, 2010, and 2020, and the ratio of population to the street area was calculated using the street as the unit. GDP data were obtained from the data of that year published by the Hangzhou Bureau of Statistics for each district in 2000, 2010, and 2020. The rate of population change and GDP change, are also used in the analysis, which is the ratio of population or GDP growth in a certain period to the base period data.

3.3.2. Spatial Morphological Dimension

Urban compactness is an important indicator of the urban spatial form [61]. It reflects the degree of compactness and dispersion of urban morphology and is also an indicator of the agglomeration of urban land. Three indicators of morphological compactness were selected for evaluation, namely, the urban land compactness index CI [60], the urban spatial compactness index CR$^1$ [62], and CR$^2$ [63]. CI reflects the compactness of land use within the city, while the latter two take the city as a whole and integrate the multifaceted morphological characteristics of irregular shapes.

The urban land compactness index CI within a given region can be expressed as:

$$\text{CI} = \sqrt{\frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} P_i}}$$  \hspace{1cm} (1)

where $S_i$ and $P_i$ are the area and perimeter of urban site $i$, respectively. The larger the CI, the more compact the spatial pattern of land use.

The urban spatial compactness indexes CR$^1$, CR$^2$ can be expressed as follows, respectively.

$$\text{CR}^1 = \frac{2\sqrt{\pi A}}{P}$$  \hspace{1cm} (2)

where $A$ and $P$ are the area and perimeter of the built-up area of the city, respectively. The compactness of the area of any shape CR$^1$ is less than 1. CR$^1$ The closer to 1, the more compact the spatial shape is; the smaller the value, the greater the degree of dispersion, indicating that the spatial shape is less compact.

$$\text{CR}^2 = \frac{A}{A'}$$  \hspace{1cm} (3)

where $A$ is the area of the built-up area of the city and $A'$ is the area of the minimum external circle of the area. The minimum external circle area is used as a standard to measure the shape characteristics of the city. When CR$^2$ is 1, it means that the city/region area is consistent with the minimum outer circle area and the city/region is the most compact spatial shape. The compactness of the area of any shape CR$^2$ is less than 1. CR$^2$ The closer to 1, the more compact the shape is.

3.3.3. Spatial Organization Dimension

Three indicators were selected in this dimension: equilibrium degree of land use, traffic network density, and public service facility density. The equilibrium degree of land use is evaluated using the proportion of each land use and information entropy in 2000, 2005, 2010, and 2020, with the following formula.

$$H = - \sum_{i=1}^{n} B_i \ln B_i$$  \hspace{1cm} (4)

$$J = \frac{H}{H_{\text{max}}} = - \sum_{i=1}^{n} B_i \ln B_i / \ln n$$  \hspace{1cm} (5)
where \( i \) represents each land-use type, \( B \) refers to the proportion of land area to the total area, \( H \) is the information entropy of land-use structure, and \( J \) is the equilibrium degree of land-use structure.

Traffic network density was extracted from the main traffic arteries in the study area in 2005, 2010, and 2016 for line density analysis. Public service density analysis was conducted using the available data of the study area in 2010 and 2016, which included administrative institutions and major research and education, health care, culture and entertainment, postal, and financial service points. These two indicators are used to reflect the convenience of transportation and the equalization of public services under polycentric spatial development. The density around each raster was estimated based on its traffic or public facility density value, and the optimal search radius for this study was selected by comparing the results of density analysis under different search radii.

3.3.4. Ecological Quality Dimension

The remotely sensed ecological indicator (RSEI) was selected in the dimension of ecological quality dimension [64]. The RSEI was obtained from four aspects of greenness, temperature, humidity, and dryness indicators using principal component analysis (PCA). The study used Landsat remote sensing image data for five years, 2000, 2005, 2010, 2015, and 2020, for the calculation.

\[
\text{RSEI} = f(\text{Greenness, Wetness, Heat, Dryness}) \tag{6}
\]

where Greenness is reflected by the Normalized Vegetation Index (NDVI), Wetness is expressed by soil moisture (TCT), Heat is expressed by surface temperature (LST), and the dryness index is represented by the Normalized Soil Difference Index (NDSI) [65].

The data used in this study include various types of remote sensing images, land-use data, urban transportation, and public facilities data, administrative spatial data, and population census data of the study area. Among them, Landsat 8 satellite images with a resolution of 30 m × 30 m were downloaded from the geospatial data cloud website. The land-use data were interpreted based on remote sensing images and divided into arable land, forest land, grassland, water, towns, rural settlements, and unused land. The raster data had a uniform resolution of 200 m × 200 m. The population data for 2000, 2010, and 2020 were obtained from the fifth, sixth, and seventh national census respectively, and the urban traffic and public facilities data and administrative spatial data were collected from Hangzhou Construction Bureau and Land Resources Management Department. All data were loaded into the ArcGIS software platform to unify data spatial reference for spatial data analysis and measurement.

4. Results


The fifth census data of Hangzhou show that the distribution range of highest value areas of population density in 2000 is basically concentrated in the old city area around Wulin Square. By 2010, the range of the original highest value area of population density expands outward in a circle, while higher value areas begin to appear in Linping city, Xiasha city, and Jiangnan city. This trend continues to strengthen in 2020, with the population density of the areas connected to the main city both showing larger increases and the core areas of the subcities approaching the population density of the main city (Figure 2). In general, comparing the population growth of the main city and the subcities from 2000–2020, the main city still maintains the leading growth in population numbers, while Linping city and Jiangnan city are slightly lower. However, the growth rate of the main city is the lowest during the study period, with Xiasha and Linping cities leading the population growth rate (Table 2). In particular, the establishment of the Xiasha Economic Development Zone and the University City had a greater effect on the population gathering in this area during 2000–2010, making the population growth of Xiasha city the most significant of all.
The changes in GDP also show a bias towards aggregation. In 2000, the highest total GDP in Hangzhou was in the Xiaoshan district, with the Shangcheng district and the Xihu district being the better-developed areas. By 2015, Xiaoshan still maintained its leading position, while Jianggan and Yuhang districts started to maintain a higher growth rate. Yuhang district reached 305.161 billion yuan in 2020 to surpass Xiaoshan as the district with the highest GDP and is also the first district (county or city) in Zhejiang with a GDP exceeding 300 billion yuan (approximately 44.34 billion USD). In terms of the rate of change in GDP, Binjiang and Yuhang are the most significant ones throughout the study period, with Xiaoshan and Yuhang both maintaining high growth rates from 2000 to 2010, with little difference in other regions; meanwhile, Binjiang is the region with the most significant GDP growth rate during 2010–2020, followed by Yuhang district (Table 3).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shangcheng</td>
<td>0.0283</td>
<td>0.0380</td>
<td>0.0674</td>
<td></td>
</tr>
<tr>
<td>Xiaocheng</td>
<td>0.2757</td>
<td>0.0766</td>
<td>0.1780</td>
<td></td>
</tr>
<tr>
<td>Jianggan</td>
<td>0.7665</td>
<td>0.4896</td>
<td>1.6314</td>
<td></td>
</tr>
<tr>
<td>Gongshu</td>
<td>0.2856</td>
<td>0.1508</td>
<td>0.4794</td>
<td></td>
</tr>
<tr>
<td>Xihu</td>
<td>0.3821</td>
<td>0.3573</td>
<td>0.8759</td>
<td></td>
</tr>
<tr>
<td>Binjiang</td>
<td>1.7524</td>
<td>0.5796</td>
<td>3.3477</td>
<td></td>
</tr>
<tr>
<td>Xiaoshan</td>
<td>0.2254</td>
<td>0.4075</td>
<td>0.7248</td>
<td></td>
</tr>
<tr>
<td>Yuhang</td>
<td>0.4312</td>
<td>1.0529</td>
<td>1.9381</td>
<td></td>
</tr>
</tbody>
</table>

The population in 2020 is still counted by the administrative divisions used in the sixth national census.
Analysis of the socioeconomic dimension shows that the population and economy of the main city remain relatively stable, but new hotspots of rapid growth have emerged in its surrounding areas. In comparison, Xiasha city, located in the Jianggan district, has a more obvious population gathering driven by industries and university cities; Jiangnan city, with Binjiang and Xiaoshan city as its core, has a higher growth rate than the main city, although the population increase is not as high as the other two subcities and is second only to Yuhang district in terms of GDP performance. The population of the Yuhang district is concentrated in the core area of Linping city and the area connected with the main city and Xiasha city. Thanks to the landing of famous universities and research institutes in Yuhang, the introduction of R&D and operation headquarters of companies such as OPPO, Vivo, Byte Jump, and Ubiquity, as well as Dream Town, Quzhou Haichuang Park, and Hanghai New District, the comprehensive capacity of this area has been greatly enhanced and the economy has grown by leaps and bounds.

4.2. The Spatial Pattern of Land Use Is Less Compact and More Discrete

The measurement of the three compactness indicators is consistent overall, and the results show that the compactness of urban spatial form generally presents a decreasing trend during the period 2000–2020 (Table 4). Taking 2015 as the cut-off point, it can be divided into two stages: first decreasing and then increasing. During the period 2005–2010, while the main urban area expanded outward, the spatial pattern of “one main, three vice, and six clusters” was established, and independent high-tech development zones, industrial zones, and university cities were developing rapidly on the periphery of the city. During this period, the urban development adopted a mixed land-use approach, the distribution of land types was extremely scattered, the complexity of spatial edges increased, and the spatial compactness of the city CI, CR\(^1\), and CR\(^2\) decreased rapidly, showing an outward development pattern; then the three vice cities developed rapidly and gradually formed a spatial connection with the main city, changing from point-like development to axial development. After 2010, the urban spatial compactness index CR\(^1\) showed a steady increase, and only in 2015 did the CI and CR of urban spatial compactness start to rise. This comparison shows that after the initial development of the subcities, the built-up area expands outward in independent clusters, with a variety of land-use types, but is relatively balanced in all directions, and does not appear to be concentrated in only one direction. By 2020, the discrete degree of urban expansion increases, but the balanced degree of each direction continues to improve. The results of the urban spatial compactness calculation reveal that, in general, the urban land use and spatial form of Hangzhou are relatively discrete, and the city is still in a polarized development trend of outward expansion.

<table>
<thead>
<tr>
<th>Year</th>
<th>CI</th>
<th>CR(^1)</th>
<th>CR(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.0445</td>
<td>0.3437</td>
<td>0.3417</td>
</tr>
<tr>
<td>2005</td>
<td>0.0360</td>
<td>0.2315</td>
<td>0.2006</td>
</tr>
<tr>
<td>2010</td>
<td>0.0358</td>
<td>0.2294</td>
<td>0.2037</td>
</tr>
<tr>
<td>2015</td>
<td>0.0369</td>
<td>0.2633</td>
<td>0.2306</td>
</tr>
<tr>
<td>2020</td>
<td>0.0378</td>
<td>0.2366</td>
<td>0.2684</td>
</tr>
</tbody>
</table>

4.3. The Balance of Land-Use Structure Has Improved and the Spatial Organization Centre Has Diverged

The equilibrium degree of the land-use structure in Hangzhou from 2000 to 2020 is firmly increasing (Table 5). In 2000, the land-use structure information entropy was 1.3994, which was the lowest during the study period, indicating that the orderliness of the land-use system is higher at this time. The gradual increase of land-use equilibrium degree and land-use structure information entropy reflects the gradual increase in the land-use mixing degree and the gradual decrease in the land-use system orderliness. Comparing the proportion of land use, this trend is mainly due to the increase in land for
construction, agricultural restructuring, and land destruction, which makes the proportion of towns, settlements, and unused land, which originally had a lower proportion, increase significantly, while the proportion of forestland and arable land, which originally had an absolute advantage, decrease. From an intracity perspective, the equilibrium of the main city remains relatively stable with a small increase throughout the study period and is higher than that of the other three subcities. The main city has a more mixed land-use structure and undertakes comprehensive urban functions. The equilibrium degree of Jiangnan city was close to that of the main city in 2010 and slightly decreased in 2015, mainly reflected in the sharp decrease in the proportion of dominant arable land from 50.15% to 40.73%, with a corresponding increase in the proportion of urban construction land and other construction lands such as transportation from 22.19% and 0.3040% to 29.18% and 1.22%, respectively. As the urban construction land and the arable land continue to increase and shrink, the equilibrium degree of Jiangnan city land reaches its peak and exceeds that of the main city by 2020. 2000 to 2005 was the period of rapid equalization of various types of land-use areas in Linping city, after which the land-use structure information entropy showed a trend of steady growth. In Xiasha city, its equilibrium degree showed a trend of first decreasing and then increasing, mainly because the single function of the industry was temporarily prominent in the early stage of growth of this area, and after 2005, when each functional category gradually developed, its entropy value naturally increased, and the land-use system gradually stabilized and developed in an orderly direction. The analysis of land-use equilibrium and information entropy shows that the impact of Hangzhou’s polycentric development strategy on Jiangnan city is more obvious: the larger the scale of urban construction land is, the larger the corresponding information entropy value, and accordingly, the more types of land use there are, the increase in the total number of functions, and the smaller the difference in land composition. The development of Linping city is slightly weaker than that of Jiangnan city, with a more complete set of functions. Xiasha city, on the other hand, is still in the process of gradual functional coordination development due to the prominence of a single function. The study of the information entropy and equilibrium of Hangzhou city shows that the main factor affecting the spatial variation of information entropy of land-use structure is the proportion of urban construction land.

Table 5. Land-use structural balance of Hangzhou in different years.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Main city</td>
<td></td>
<td>0.7267</td>
<td>0.7366</td>
<td>0.7537</td>
<td>0.7600</td>
<td>0.7696</td>
</tr>
<tr>
<td>Jiangnan city</td>
<td></td>
<td>0.6667</td>
<td>0.7459</td>
<td>0.7528</td>
<td>0.7428</td>
<td>0.8698</td>
</tr>
<tr>
<td>Linpin city</td>
<td></td>
<td>0.4927</td>
<td>0.6171</td>
<td>0.6495</td>
<td>0.6469</td>
<td>0.6910</td>
</tr>
<tr>
<td>Xiasha city</td>
<td></td>
<td>0.6214</td>
<td>0.5320</td>
<td>0.5869</td>
<td>0.5984</td>
<td>0.6069</td>
</tr>
<tr>
<td>Hangzhou</td>
<td></td>
<td>0.6188</td>
<td>0.6730</td>
<td>0.6887</td>
<td>0.7210</td>
<td>0.7541</td>
</tr>
</tbody>
</table>

The spatial distribution of transportation, as well as public facilities, shows the characteristic of decreasing circles with the old urban area as the core (Figures 3 and 4). The degree of aggregation in Jiangnan city is significantly stronger than that in the other two subcities. The old city, with Wulin Square as the core, is the most mature central area in Hangzhou, with a high concentration of traffic and public facilities, and decreasing towards the outer circles. The decreasing trend is the slowest towards Jiangnan city, which forms the largest contiguous zone of functional concentration, followed by Xiasha city in the east and the fastest decreasing trend to the north. Finally, a new core area of functional agglomeration is formed from the main city outward to the subcity, among which Xiasha city and Jiangnan city have the closest functional connection with the main city. The development of urban functions in Linping city is relatively slower than in the other two subcities. Specifically,
in 2005, the high-value area of traffic facility density was mainly distributed in the main city around the Hubin and Wulin streets. In addition, small independent high-value areas existed in Xiaoshan Economic Development Zone and Changhe street in Jiangnan city, and Baiyang and Xiasha street in Xiasha city. This trend became more pronounced in 2010 when the range of high-value areas in each sub-city was expanded. By 2016, the density of the transportation network increased sharply, and the high-value areas in the main city and Jiangnan city showed a trend of integration, initially forming a core area of agglomeration with the twin urban centers on both sides of the Qiantang River as nodes, and forming sublevel agglomeration areas in the periphery. The higher value areas have formed mutually independent agglomeration centers in Xiasha city and Linping city, mostly industrial parks and university cities with large land areas, and the overall show characteristics of centrifugal dispersion pattern of high agglomeration. In general, the development of the transportation network in Hangzhou is highly clustered on both sides of the Qiantang River, and the subcities are relatively scattered, with an overall spatially divergent feature of medium density and sparse circumference. The development performance is from high to low in the main city, Jiangnan city, Xiasha city, and Linping city, respectively. The spatial distribution of public facilities lags behind the construction of the transportation network. In 2010, the distribution shows that the high-density area of urban public facilities distribution is small, only in the surrounding areas of the Wulin and Changqing streets, and the trend of decreasing outward is faster. There are independent higher-value areas around Beigan street in Jiangnan city and Donghu street in Linping city, but the areas are small and mostly rely on the original public facilities in the area. By 2016, the original high-value areas remained, stretching outward to a wider extent, and the decreasing trend of circles slowed down. Higher density areas also began to appear in Xiasha city, and the outward extension gradually integrated with the periphery of the main city, forming a pattern of circle distribution with the main city as the core of centripetal clustering. In general, the polycentric development strategy is not significant in promoting the construction of public facilities in the subcities and relieving the public service functions of the main city.

4.4. Overall Decline in Ecological Quality, with Peripheral Temperature Mitigation Effects Appears

The average value of RSEI in Hangzhou from 2000 to 2020 showed a general decreasing trend, from 0.4867 to 0.3166, a decrease of 34.94%. Among them, the largest decrease of 34.22% was observed in 2010–2015, and the next largest decrease of 15.21% was observed in 2000–2005. The overall trend of a rapid decline in ecological quality in Hangzhou side-by-side reflects the fact that the advancement of urbanization in the city during this period was accompanied by the emergence of reduced vegetation, bare soil, and hardening of the ground surface, etc. (Figure 5). Unlike the economic benefits that diminish from the core of urban functions to the periphery, the ecological benefits increase from the core of the city to the periphery. Obviously, both benefits are directly related to the urban development and construction situation. In the peripheral areas, as the distance from the urban center...
increases, the vegetation and water coverage begin to expand, the ecological environment is clearly more advantageous, and the economic development level tends to decrease.

Figure 3. Traffic network density in Hangzhou in different years.

Figure 4. Public facilities density in Hangzhou in different years.

Figure 5. The RSEI in Hangzhou in different years.
To reflect the ecological environment status and distribution more intuitively, the RSEI values were divided into five grades of worst, worse, moderate, good, and excellent at an interval of 0.2 [66], and the area changes of different grades of ecological environment quality were analyzed. The overall ecological environment quality of Hangzhou is mostly good grade, and the highest area share is in 2005, reaching 48.26%. Specifically, in 2000 and 2005, the ecological quality of Hangzhou was dominated by the good grade, followed by the medium grade. In 2010, the area share of excellent grade increased, and the area share of good grade decreased to 33.66%. In 2015, the area share of the medium grade was 32.64%, and the area share of the good grade was 29.02%. By 2020, along with the proportion of excellent grades rising to 26.60%, the proportion of good and medium grade was 28.23% and 25.34% respectively, and the proportion of the three reached 80%. It is noteworthy that the proportion of the worst grade changed relatively little during this period, but the proportion of areas with worse grade increased overall, from 13.25% in 2000 to 18.95% in 2020. In general, the proportion of areas with excellent and good grade of ecological environmental quality in Hangzhou was basically stable from 2000 to 2020, while the area with worse and worst grade increased slightly, reflecting that the overall ecological environmental quality in Hangzhou did not improve significantly during this period. Compared with the spatial distribution, the core areas of excellent and good grade show a more obvious surface distribution, and the changes are mainly in the mountainous areas with higher altitudes, showing more of a banded or sporadic distribution pattern. The areas with worse and worst grade are more often found around urban built-up areas, and the ecological quality is reduced more by the adverse effects of human production and life. Combined with the change in surface temperature, the difference in surface temperature between the main city and the subcity during the study period is small, with the largest increase of 55.26% in Xiasha city, followed by Jiangnan city with 52.90%, and 46.84% and 42.77% in Linping city and the main city, respectively. It can be seen that the increasing influence of urban activities under polycentric spatial development causes more areas to be affected by rapid urbanization, which also causes the gradual fragmentation of high-value areas in the urban ecological quality and the outward expansion of the former urban core area in the high-temperature area of the ground. On the other hand, the activity intensity of the subcities gradually surpasses that of the main city, and the highest values of surface temperature begin to appear in the southern city. The high-temperature zone of subcities covers most of its area and is connected with the main city high-temperature zone. The peripheral clusters are relatively less affected and are still the core guarantee for maintaining the ecological quality of the city.

5. Discussion

The study evaluates the performance of polycentric spatial development in four dimensions: socioeconomic, spatial morphology and organization, and ecological quality. The population and economy of Hangzhou maintain steady growth, and the growth rate of subcities gradually exceeds that of main city. The spatial morphology increases in dispersion after the initial development and formation of subcities, showing the polarization development trend of outward expansion. The orderliness of the land-use system gradually decreases, and the equilibrium maintains a relatively stable small growth. The spatial organization of transportation and public facilities shows the characteristic of decreasing circles with the old city as the core, and the function of the subcities is in the process of gradual improvement. The ecological quality decreases in general, and with the expansion of the development area, the high-temperature area in the central city is alleviated, and several higher-temperature areas gradually appear in the periphery. In general, the evaluation results in four dimensions show that the performance level of Hangzhou’s polycentric spatial development has improved significantly, and presents more obvious stage and regional differences. In terms of time, the period from 2000 to 2010 was characterized by a significant spatial expansion, a decrease in compactness, and a significant outward development pattern under rapid socioeconomic growth. The population and economy of the main
city show a spatial trend of spreading outward from the center with high accumulation, and the characteristics of circle-type distribution are continuously strengthened. At this stage, the subcities are mostly in a period of rapid development and play a limited role in taking over the transfer of population from the central area. Lacking guidance and support from high-capacity rapid transit and public services, the pressure is always superimposed on the old city, resulting in a mismatch between the spatial organization and expansion patterns. During this period, the spatial development of polycentric centers was driven by exogenous forces, and the spatial form was efficient, but the transfer of functions lagged behind, and the development in terms of spatial organization and ecological quality was not synchronized. After 2010, the spatial structure of one main and three vices was initially formed, and the construction space driven by market forces grew in an infill manner. The rapid transportation system and public service construction matched with the polycentric system and became a powerful means to guide the concentration and dispersion of population and economic activities. The efficiency of the spatial organization, as well as compactness, began to gradually improve, and the function of the subcities was gradually developing and improving. Additionally, there are differences in the characteristics of spatial development performance changes in three subcities. The characteristics exhibited by the three subcities in polycentric spatial development are closely related to their development evolution. Driven by policies and planning, Linping city, Xiasha city, and Jiangnan city have emerged, but they show significant differences in socioeconomic, spatial form and organization, and ecological quality. Linping city and Jiangnan city, relying on the former Linping and Xiaoshan core areas, are second only to the main city in terms of population, economy, transportation network, and public facilities performance. In particular, after Hangzhou planned a large public construction center (Qianjiang Century City) for Jiangnan city across the river in the core block of Qianjiang New City (CBD), the center of gravity of the city slowly shifted to the south bank of Qiantang River. The river crossing tunnel of Qingchun Road, connecting Qianjiang New City and Qianjiang Century City, has accelerated the communication between the main city and Xiaoshan district, which has led to the rapid development of Jiangnan city. Xiasha city is more developed after the completion of the construction of areas such as Jiubao, integration of the main city, and acceptance of its radiation. As its establishment is mainly based on industrial parks and university cities, the function is relatively singular, and the spatial organization has a greater impact on the improvement of performance.

From the spatial and temporal characteristics of the differences, it can be seen that the important factors affecting the performance of polycentric spatial development in Hangzhou are the socioeconomic and spatial organization of urban elements. Socioeconomic development drives the urbanization process and the evolution of the spatial structure in Hangzhou. With the cooperation of policy planning, the initial establishment of Hangzhou’s polycentric spatial form was controlled and guided by the repeated administrative division adjustments that expanded the urban development space. After that, the city “expanded eastward, tourism moved westward, developed along the river, and developed across the river”, and adopted a combination of point and axis expansion, initially forming a cross-river, along-river, and networked group layout with the Qiantang River as the axis, which laid the foundation for the subsequent urban development. Macro development strategies, development, and construction-related policies, and urban master planning all play an important role in the distribution of urban functions. However, even with the impetus of exogenous forces, the spatial performance at this stage is still at a low level. With the economic development of different centers and the improvement of spatial organization and functions, the elements clustered in the original urban center spread rapidly and recollected in the subcenters, and the spatial development performance improved rapidly. Along with the new opportunities brought by various internet enterprises as well as the information industry, G20 Summit, and Asian Games, the pace of infrastructure and ecological environment construction has been significantly accelerated, which has
promoted the continuous concentration of functional elements in the three subcities and the spatial pattern of urban polycentric functions has gradually matured.

6. Conclusions

The study established the evaluation system of polycentric spatial development performance and used it to evaluate the study area. The results show that the spatial development performance of Hangzhou has improved significantly, and shows more obvious characteristics of stage and regional variations. This characteristic well illustrates that urban spatial development driven by market forces is significantly stronger in terms of diffusion effect and sustainability than that driven by exogenous forces. The performance of subcities has rapidly enhanced due to the integration and radiation effects with the main city. At the same time, in the process of polycentric spatial formation, the spatial pattern initially shows loose spatial results, but through the connectivity and balanced allocation of transportation networks and public services, the compactness and organizational efficiency of the polycentric spatial pattern can be effectively improved. For Hangzhou to take the form of a cross-river and county to expand the development space, building a polycentric spatial structure has affected the urban spatial performance to some extent. Even if the compactness of the spatial structure decreases with the growth of the city, the spatial organization efficiency can still be better if the connectivity of the transportation network is improved and the balanced allocation of public service facilities at all levels is emphasized. The efficient and orderly spatial structure and organization can further enhance the socioeconomic level and reduce the impact on the ecological quality so that the urban spatial growth of the city can still have a good performance.

Regulating the spatial performance of large cities needs to be considered from multiple dimensions. Ensuring reasonable, fair, and effective allocation of spatial resources is a prerequisite for improving spatial performance. A spatial intervention mechanism is formulated to establish a reasonable system of resource acquisition and allocation by strengthening the evaluation of constraint indicators such as land resources, infrastructure, and ecological environment. The study evaluates and analyses Hangzhou’s polycentric spatial performance in four dimensions: socioeconomic, spatial form and organization, and ecological quality, and clarifies that urban polycentric spatial development has been effective to a certain extent. However, limited by the availability of data, there are limitations in the study precision and the selection of the time cross-section. In the future, we can also explore the inclusion of production input and resource consumption indicators such as energy consumption, effective investment in land resources and infrastructure, and environmental management to construct a quantitative evaluation system of spatial performance with more dimensions and levels, reflecting the diverse characteristics of urban polycentric spatial development, continuously optimizing and adjusting the urban spatial structure, and improving the overall effectiveness and coordination of polycentric space.

Author Contributions: Conceptualization, L.Z. (Liang Zhang); methodology, L.Z. (Liang Zhang) and X.L.; software, L.Z. (Liang Zhang) and X.L.; validation, L.Z. (Liang Zhang), L.Z. (Linlin Zhang) and X.L.; formal analysis, L.Z. (Linlin Zhang); investigation, L.Z. (Liang Zhang); resources, L.Z. (Liang Zhang) and X.L.; data curation, L.Z. (Liang Zhang) and X.L.; writing—original draft preparation, L.Z. (Liang Zhang); writing—review and editing, L.Z. (Linlin Zhang) and X.L.; visualization, L.Z. (Liang Zhang); supervision, L.Z. (Linlin Zhang); project administration, L.Z. (Liang Zhang); funding acquisition, L.Z. (Liang Zhang), L.Z. (Linlin Zhang) and X.L. All authors have read and agreed to the published version of the manuscript.

Funding: The research is supported by Philosophy and Social Sciences Foundation of Zhejiang Province (No. 21NDQN270YB, No. 20NDQN294YB), the Natural Science Foundation of Zhejiang Province (No. LQ20D010004), Fundamental Research Funds for the Central Universities (No. 2021ECNU-HWCBFBLW002) and the China Postdoctoral Science Foundation (No. 2021M701210).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.
Data Availability Statement: The data presented in this study are available on request from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

References
17. Ostrom, E. Beyond markets and states: Polycentric governance of complex economic systems. Am. Econ. Rev. 2010, 100, 641–672. [CrossRef]
26. Lambregts, B. Polycentrism: Boon or barrier to metropolitan competitiveness? The case of the Randstad Holland. Built Environ. 2006, 32, 114–123. [CrossRef]
31. Krugman, P. Confronting the mystery of urban hierarchy. J. Int. Econ. 1996, 10, 399–418. [CrossRef]