

Article

Spatial-Temporal Coupling Coordination Relationship between Urban Green Infrastructure Construction and Economic Development in China

Weiwei Wang , Yanping Wen , Wanxu Chen  and Yiran Qu

School of Geography and Information Engineering, China University of Geosciences, Wuhan 430078, China; wangweiw@cug.edu.cn (W.W.); cugcwxc@cug.edu.cn (W.C.); quyiran@cug.edu.cn (Y.Q.)

* Correspondence: wenyanning@cug.edu.cn

Abstract: Urban green infrastructure construction and economic growth are necessary ways and important supports to promote sustainable development. Exploring their coupling coordination relationship is important for achieving high-quality economic development. This study uses the entropy method, coupling coordination degree, kernel density estimation, the Dagum Gini coefficient, and spatial autocorrelation to explore the spatial-temporal pattern characteristics and coupling coordination relationship between green infrastructure construction and economic development for 273 cities in Chinese mainland in 2010–2020. The results show that the level of China's green infrastructure construction and economic development gradually increased during 2010–2020. There were significant regional differences in space, exhibiting a decreasing spatial pattern from east to west. The coupling coordination degree was constantly improving. The overall Gini coefficient shows an upward trend. Among the four regions, eastern China has the greatest intraregional variation. The uneven level of coupled coordination is mainly from interregional variation. There was a significant positive spatial autocorrelation relationship, and cities that had a higher degree of coupling coordination tended to agglomeration development. Meanwhile, it also had certain spatial heterogeneity. China's entire level of coupling coordination degree still has much room for improvement. The study is of great significance in reducing disparities between regions and strengthening regional spatial coordination development.

Keywords: green infrastructure construction; economic development; coupling coordination; the Dagum Gini coefficient; spatial autocorrelation; sustainable urban development



Citation: Wang, W.; Wen, Y.; Chen, W.; Qu, Y. Spatial-Temporal Coupling Coordination Relationship between Urban Green Infrastructure Construction and Economic Development in China. *Land* **2024**, *13*, 1095. <https://doi.org/10.3390/land13071095>

Academic Editors: Hrvoje Tomić, Miodrag Roić, Goran Andlar, Jaroslaw Janus and Thomas Panagopoulos

Received: 21 May 2024
Revised: 13 July 2024
Accepted: 18 July 2024
Published: 19 July 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Green infrastructure is a new concept based on ecological theory [1]. Its application practice can date back to the appearance of early urban parks in the West in response to the social and ecological impacts of the Industrial Revolution [2,3]. It describes an interlinked network of green spaces consisting of natural regions and artificially constructed green open spaces designed to improve overall environmental quality and provide public utility services [4,5]. Some scholars have also argued that it is reflected in the ecological transformation of traditional infrastructures, including road engineering, drainage, energy, solid waste treatment systems, and so on [6]. Scholars have conducted a large number of research on green infrastructure and have widely applied it to formulate policies for sustainable development [7]. Relevant research disciplines mainly focus on environmental sciences and urban studies [8], and the research hotspots mainly focus on exploring its impacts on regulating climate change, reducing environmental pollution [9], mitigating the heat island effect [10], biodiversity conservation, green roofs, and rainwater management. The theoretical approaches include the green infrastructure assessment tool, the cost-benefit analysis assessment methodology, the ecological performance of urban-rural space utilization, and morphological spatial pattern analysis methods [11–14]. Wang, Y.Z. [15]

used Circuitscape software to further optimize the urban green infrastructure network pattern. The research field of green infrastructure has been deepening with the gradual maturation of research methods and tools and the extensive use of remote sensing and GIS technologies. Most scholars focus on green space or landscape change at the municipal or regional scale when they examine the spatial-temporal variation of green infrastructure and its motivating elements [16–18]. Green infrastructure has gained widespread popularity to cope with the negative impacts of urbanization, and its economic viability has attracted discussions among scholars, investors, and urban planners.

The relationship between urban green infrastructure construction and economic growth is interconnected and mutually beneficial. Green infrastructure can provide a livable environment for urban residents [19] and reduce energy consumption and resource wastage [20]. In addition, it can also attract high-quality talents and high-tech enterprises, optimize the economic and industrial structure, increase employment opportunities [21], save urban management costs, and drive the prosperous growth of the regional economy and society. Meanwhile, a thriving urban economy can provide financial security and technical support for further green infrastructure. So, they form a virtuous circle. However, traditional economic development models often overlook environmental considerations, leading to environmental degradation that, in turn, hinders economic growth, creating a vicious cycle. In essence, the coupling and coordination of urban green infrastructure construction and economic growth are pivotal in addressing environmental challenges and propelling high-quality economic development. Neglecting this crucial link will result in environmental deterioration, stunted economic progress, and diminished urban competitiveness, ultimately undermining sustainable urban development. Therefore, it is essential to integrate these two aspects seamlessly and advance them together to achieve sustainable urban development goals.

In the majority of current studies about the connection between green infrastructure and economic development, they focus on the financial advantages of urban green infrastructure construction and its impact on economic and social development. In order to attract investment and promote rational urban planning and construction, UNEP-WCMC recommends estimating the economic worth of landscape resources [22]. Scholars have employed various methods to evaluate the economic worth of green infrastructure investments, such as cost-benefit and multiplier analysis [23], the total economic value evaluation model [24], and input-output analysis. Galvin [25], for example, using data from a survey of GI construction firms, determined annual, direct GI investment and constructed an input-output model to estimate indirect and induced economic impacts at the regional scale. Some studies have also found that urban green infrastructure investment has an important influence on the real estate and commercial markets [26], promoting residents' consumption willingness and driving urban economic growth and regional development. Other studies have investigated the influence mechanism of green infrastructure on urban or rural economic growth. Researchers have employed dynamic panel and simultaneous equation models, spatial Durbin models, and spatial econometric models to analyze this relationship. For instance, Zhou Qiang [27] uses the fixed asset investment in infrastructure construction, such as landscaping, sewage sludge treatment, and city appearance and environmental sanitation, to measure the construction of urban environment and green infrastructure, explores its impact mechanism on the high-quality development of urban economy. He Minwen [28] developed a comprehensive green infrastructure evaluation system encompassing five key aspects: area, allocation, intensity, accessibility, and morphology. This system also considered the specific characteristics of different spaces (mountains, waterfronts, and roads) to assess their individual GI levels. To analyze the relationships between urban function and development levels and the construction level of green infrastructure, He employed grey correlation degree and coupling coordination degree methods. This approach allowed for a comprehensive understanding of the degree of mutual interaction and interdependence between these elements. Cui Y [29] selected five indicators to reflect the level of green infrastructure, including forest coverage, wetland area, natural protection areas, landscaping rate, and per capita park area. The coupling coordina-

tion degree model was used to evaluate and compare the coordinated development levels among industrialization, environmental carrying capacity, and green infrastructure in the Beijing–Tianjin–Hebei region. Zhang Feng [30] established a more comprehensive evaluation index system for green infrastructure based on the economic, social, and ecological functions of green infrastructure. The entropy weight method and technique for order preference by similarity to the ideal solution (TOPSIS) model were used to determine the evaluation index weight, and the clustering method was used to analyze the form factors of the multifunctional value of green infrastructure in different regions. Peng BH [31] also makes use of the entropy method, coupled coordination degree model, and spatial auto-correlation analysis to explore the external correlation and internal relationship between the environment and the economy from the perspective of coupling coordination.

While the economic benefits and influence mechanisms of green infrastructure have been extensively studied, there's a growing need to understand the intricate coupling and coordination relationship between green infrastructure construction and economic growth. Previous studies often lack a comprehensive spatial-temporal analysis, failing to capture the dynamic interplay between green infrastructure and economic development across different regions and time periods. This requires a more holistic perspective that considers the spatial–temporal interactions and interdependencies between these two key factors. This study contributes to the existing literature by delving deeper into the complex coupling and coordination relationship between green infrastructure construction and economic growth, a crucial aspect often overlooked in existing studies.

In order to more specifically study the coupling and coordination relationship between green infrastructure construction and economic development, this study selected 273 cities on the Chinese mainland from 2010 to 2020, considering data availability, and adopted a comprehensive methodological approach that integrates multiple techniques. First of all, this paper selects representative green infrastructural construction indicators and economic development indicators to construct the evaluation index system of the two systems, respectively. The entropy value method is used to measure the development level of the two and carry out a comparative analysis to analyze the external influence of each, respectively. Secondly, based on the establishment of the coupling coordination degree model, the intrinsic correlation between the two is explored from the perspective of time and space. Finally, by combining various spatial analysis techniques, such as kernel density estimation, Dagum Gini coefficient and its decomposition, and spatial autocorrelation, we are able to analyze the spatial distribution, concentration, regional differences, and spatial heterogeneity of the degree of coupling and coordination between Chinese cities, providing a multi-dimensional understanding of the coupling and coordination relationship. This study is helpful in realizing the synergy between green infrastructure construction and economic development under the background of promoting Chinese modernization and building a beautiful China where man and nature live in harmony. Additionally, it is also of great significance in promoting sustainable urban development and high-quality economic growth, enhancing residents' environmental comfort, and facilitating the construction of a livable, green, resilient, intelligent, and humanistic city.

2. Materials and Methods

2.1. Study Area

China has been split into four major economic regions: eastern China, northeastern China, central China, and western China (Figure 1), based on the new situation of future development strategies. Eastern China, leveraging its coastal advantages, has propelled high levels of economic development and urbanization. The three eastern urban agglomerations—the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta—serve as the core engines of China's economic growth. The Shandong Peninsula urban agglomeration, a key development area for Shandong Province, is also a significant urban concentration in eastern China. Northeast China, in contrast, faces challenges in economic revitalization and environmental sustainability, making it a crucial

area for studying the relationship between green infrastructure and economic development. Central China plays a critical role in connecting the east and west, focusing on industrial development and agricultural production. The Middle Reaches of the Yangtze River urban agglomeration, spanning across Hubei, Hunan, and Jiangxi provinces, is a key area for driving the development of the Yangtze River economic belt and promoting the rise of central China. Its significant position underscores its importance in China's overall economic and social development landscape. Western China, experiencing rapid economic growth and infrastructure development, presents unique opportunities for sustainable development strategies. The Chengdu–Chongqing urban agglomeration is a prominent example of this growth in the western region. The study focuses on mainland China and excludes Hong Kong, Macau, and Taiwan due to data availability constraints. Some cities in mainland China were also excluded from the study due to a lack of statistical information. Nine cities, including Ankang in Shaanxi Province, Bijie, Tongren, and Liupanshui in Guizhou Province, Lincang and Yuxi in Yunnan Province, as well as Wuwei, Jiuquan, and Zhangye in Gansu Province, had missing data on green infrastructure investment in some years, which the study supplemented with linear interpolation using data from the remaining years. The final sample involved 273 cities at the prefecture level and above in China.

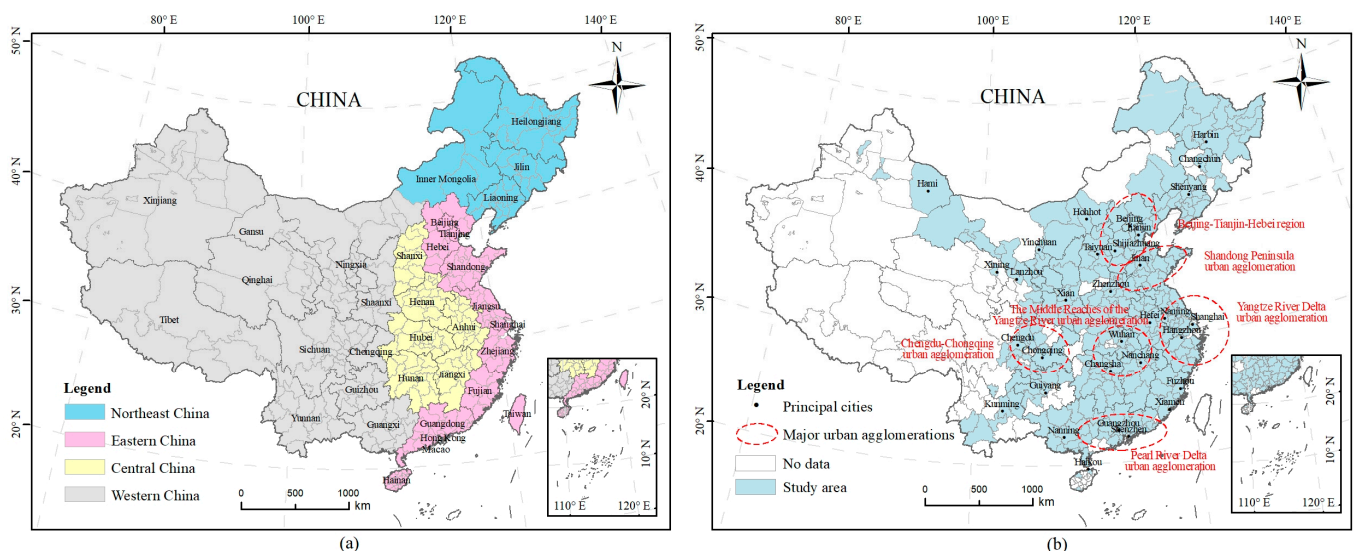


Figure 1. Map of China: (a) four major economic regions of China and (b) distribution of all cities in the study area and the major cities and urban agglomerations.

2.2. Data Sources

Relevant statistical data on cities from 2010 to 2020 can be obtained from the *Statistical Yearbook of Chinese Cities* and the *Statistical Yearbook of Urban Construction of China* issued by the Ministry of Housing and Urban-Rural Development. The Ministry of Natural Resources' standard map service system provided the vector map data utilized in the study.

2.3. Methods

Figure 2 shows the research framework. Firstly, the entropy method was used to measure the level of 273 Chinese cities' green infrastructure construction and economic development in 2010–2020 based on the indicator systems that were established. The temporal evolution and spatial pattern distribution characteristics of both were explored separately. Secondly, the excellence of each city's synergistic relationship between green infrastructure and economic development was evaluated using the coupling coordination degree model. Thirdly, the distribution evolution trend, regional variations, and spatial correlation of the coupling coordination degree were examined using kernel density estimation, the Dagum Gini coefficient and decomposition, and spatial autocorrelation. Finally, the results are discussed, and recommendations are made for typical regions.

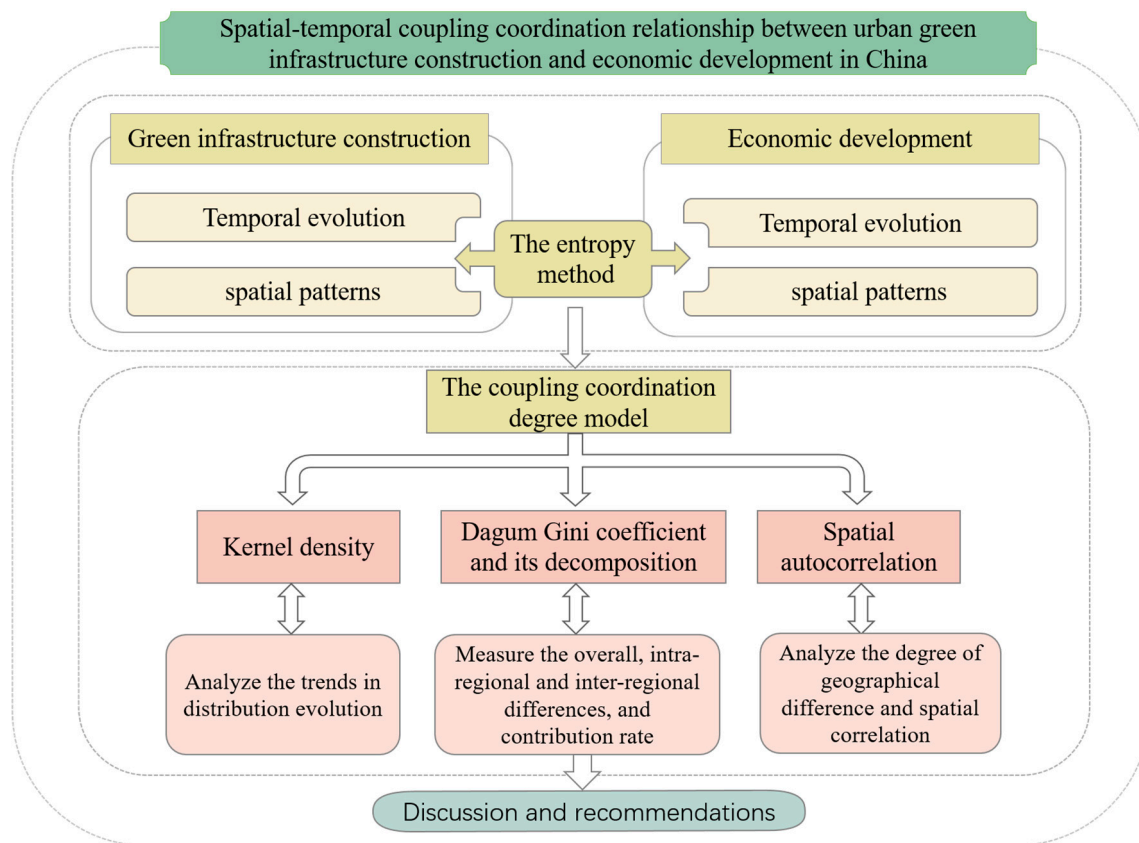


Figure 2. Research framework.

2.3.1. Building the Indicator System

Following the principles of comprehensiveness, scientificity and data accessibility, and learning from the relevant literature research [27,32], this study chose 11 indicators from the three dimensions of drainage facilities, city appearance and sanitation, and landscaping in 273 cities in mainland China to characterize the urban green infrastructure construction level. Five indicators were chosen to characterize the urban economic development level (Table 1).

Table 1. Evaluation index system of green infrastructure construction and economic development level.

System	Category of Analysis	Indicator
The level of urban green infrastructure construction	Drainage facility	Density of sewers
		Wastewater treatment rate
		Investment in sewerage
	City appearance and sanitation	Domestic garbage treatment rate
		Investment in environmental sanitation
		Area of parks and green space
		Green coverage rate of the built district
	Landscaping	Green space rate of the built district
		Public recreational green space per capita
		Number of parks
Level of economic development	Economic development	Investment in landscaping construction
		Per capita GDP
		Gross regional product
		Proportion of tertiary industry in regional GDP
		Local general public budget revenue
		Local general public budget expenditure

2.3.2. The Entropy Method

The entropy method has become a common method for the comprehensive evaluation of system development [33]. The entropy method was employed in this study to measure all indicators weights of green infrastructure and economic development and make a comprehensive evaluation. The measurement unit of each indicator was usually not uniform. Firstly, the data were standardized by range standardization, and then each indicator's weight was calculated. The specific formulas were as follows:

$$E_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (1)$$

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad (2)$$

$$w_j = \frac{1 - E_j}{\sum_{j=1}^m 1 - E_j} \quad (3)$$

$$U_i = \sum_{j=1}^m w_j x_{ij} \quad (4)$$

where x_{ij} is the standardized data, n is the number of samples, m is the number of indicators, p_{ij} is the probability of the j value of the i -th city to the sum of all the sample values of the indicator, E_j is the information entropy of the j -th indicator, w_j is the weight of the j -th indicator, and U_i is the comprehensive score of each system (i.e., green infrastructure construction or economic development).

2.3.3. The Coupling Coordination Degree Model

The coupling degree is often used to assess the degree of connection, interdependence, and mutual influence among separate systems [34]. In order to examine the excellence of the synergistic relationship between green infrastructure and economic development in each city, the study applied the coupling coordination degree model. The calculation formulas are as follows:

$$C = 2 \times \frac{\sqrt{U_1 \times U_2}}{U_1 + U_2} \quad (5)$$

$$T = \alpha U_1 + \beta U_2 \quad (6)$$

$$D = \sqrt{C \times T} \quad (7)$$

where U_1 is the comprehensive score of the urban green infrastructure construction, and U_2 is the comprehensive score of the urban economic development. C represents the coupling degree between the two, T is the coordination index, D is the coupling coordination degree between the two, α and β are the coefficients of green infrastructure and economic development, respectively, and $\alpha + \beta = 1$. In this study, it is considered that urban green infrastructure and economic development are equally important in the process of social development, so $\alpha = \beta = 0.5$. Depending on the size of the D value, the coupling coordination degree is subdivided into five grades (Table 2), with references to pertinent study material [35–37].

Table 2. Coupling coordination degree classification standards.

D Value Interval of Coupling Coordination Degree	Coordination Grade	Coupling Coordination Degree
[0.0~0.2)	1	Serious imbalance
[0.2~0.4)	2	Mild imbalance
[0.4~0.6)	3	Marginal coordination
[0.6~0.8)	4	Moderate coordination
[0.8~1.0]	5	Excellent coordination

2.3.4. Kernel Density Analysis

A nonparametric technique for estimating probability density functions is kernel density estimation [38]. It operates by interpolating a surface through discrete sample points, effectively replacing histograms with smooth density curves. This approach offers a more accurate and smoother depiction of a variable's distribution pattern, leveraging its superior statistical properties. The study analyzed the distribution pattern and change trend of the coupled coordination degree in Chinese cities using kernel density estimation.

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{X_i - x}{h}\right) \quad (8)$$

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \quad (9)$$

where n is the number of study areas, h is the bandwidth, x is the mean value, X_i is the i -th data point, $K(x)$ is the kernel function, and the Gaussian kernel function is chosen for this study, and $f(x)$ denotes the density function of the coupling coordination degree.

2.3.5. Dagum Gini Coefficient and Its Decomposition

In order to reveal the size of the spatial differences and their sources in Chinese cities, the Dagum Gini coefficient and its decomposition method were utilized to measure the overall differences, intra-regional differences, inter-regional differences, and contribution rate of the coupling coordination degree. The calculation formulas are as follows [39]:

$$G = \frac{1}{2\bar{y}n^2} \left(\sum_{i=1}^n \sum_{r=1}^n |y_i - y_r| \right) = \sum_{j=1}^k \sum_{h=1}^k \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}| / 2n^2\bar{y} \quad (10)$$

$$G_{jj} = \frac{1}{2\bar{y}_j} \left(\sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |y_{ji} - y_{jr}| \right) / n_j^2 \quad (11)$$

$$G_w = \sum_{i=1}^{n_j} G_{jj} P_j S_j \quad (12)$$

$$G_{jh} = \left(\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}| \right) / n_j n_h (\bar{y}_j + \bar{y}_h) \quad (13)$$

$$G_{nb} = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} (P_j S_h + P_h S_j) D_{jh} \quad (14)$$

$$G_t = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} (P_j S_h + P_h S_j) (1 - D_{jh}) \quad (15)$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \quad (16)$$

$$d_{jh} = \int_0^\infty dF_j(y) \int_0^y (y-x) dF_h(x) \quad (17)$$

$$p_{jh} = \int_0^\infty dF_h(y) \int_0^y (y-x) dF_j(x) \quad (18)$$

$$G = G_w + G_{nb} + G_t \quad (19)$$

where G is the overall Gini coefficient, k is the total number of regions, and n_j (n_h) is the number of cities in region $j(h)$. y_{ji} (y_{hr}) denotes the coupling coordination degree of any city in region $j(h)$ and $\bar{y}$ is the mean. $j, h = 1, 2, 3, \dots, k$; $i, r = 1, 2, 3, \dots, n_j(n_h)$. $P_j = n_j/n$, $S_j = n_j \bar{y}_j / n \bar{y}$. G_{jj} is the intra-regional Gini coefficient, D_{jh} represents the interaction of coupled coordination degree values between regions, d_{jh} measures the disparity of values between regions, and p_{jh} represents the hypervariable first-order moments. $F_j(F_h)$ represents the cumulative distribution function of the coupled coordination degree values for region $j(h)$, G_{jh} is the inter-regional Gini coefficient, G_w is the intra-regional variation, G_{nb} is the inter-regional variation, and G_t is the hypervariable density.

2.3.6. Spatial Autocorrelation

Spatial autocorrelation is a statistical method that can be used to analyze the degree of geographical difference and spatial correlation between regions. In spatial econometrics, there are many methods for testing the degree of spatial dependence. The method that is frequently employed is Moran's I statistic. This study was implemented using ArcGIS 10.6 and its associated spatial analysis tools. The analysis assessed both global and local spatial autocorrelation, revealing the spatial correlation characteristics of the coupling and coordination degree between urban green infrastructure construction and economic development.

3. Results

3.1. Spatial-Temporal Pattern Analysis in Green Infrastructure Construction

During 2010–2020, China's overall level of urban green infrastructure construction remained weak, showing an annualized increased tendency (Figure 3). The national average level was 0.0242 in 2010 and increased to 0.0378 in 2020. The urban green infrastructure construction level in eastern China increased progressively from 0.0385 to 0.0572 above the national average. There was a small gap in central and western China, and their green infrastructure construction level were both showing a fluctuating upward trend and below the national average. However, the urban green infrastructure construction level in northeastern China was extremely slow, and the gap with other regions has gradually widened since 2013.

From 2010 to 2020, the urban green infrastructure construction level in China varied significantly by area, and the regional differences were gradually expanding (Figure 4). In 2010, only Beijing, Shanghai, Guangzhou, Shenzhen, and Dongguan were considered first-tier cities, and by 2020, there were additional cities such as Tianjin, Nanjing, Wuhan, Chengdu, Chongqing, and Xi'an. Most of these cities were located in China's Yangtze River economic belt and coastal economic belt, which had higher levels and quality of development and had taken the lead in strengthening green infrastructure construction. There were 23 second-tier cities in 2020, mostly provincial capitals. With faster economic development levels and higher urbanization levels, these cities were gradually improving their urban public service facilities and municipal utilities. In 2020, the number of third-tier cities increased to 110, mainly distributed in eastern China, around the first and second-tier cities, reflecting the obvious spatial proximity effect and gradually forming a cross-regional green infrastructure network. The number of fourth-tier cities gradually decreased from 205 to 129, and the scale and development level of green infrastructure in these cities were relatively low. As a whole, in terms of green infrastructure, the Beijing–Tianjin–Hebei, Yangtze River Delta, and Pearl River Delta city clusters in eastern coastal China were

the most developed regions, while the remote cities in central and western China were relatively backward.

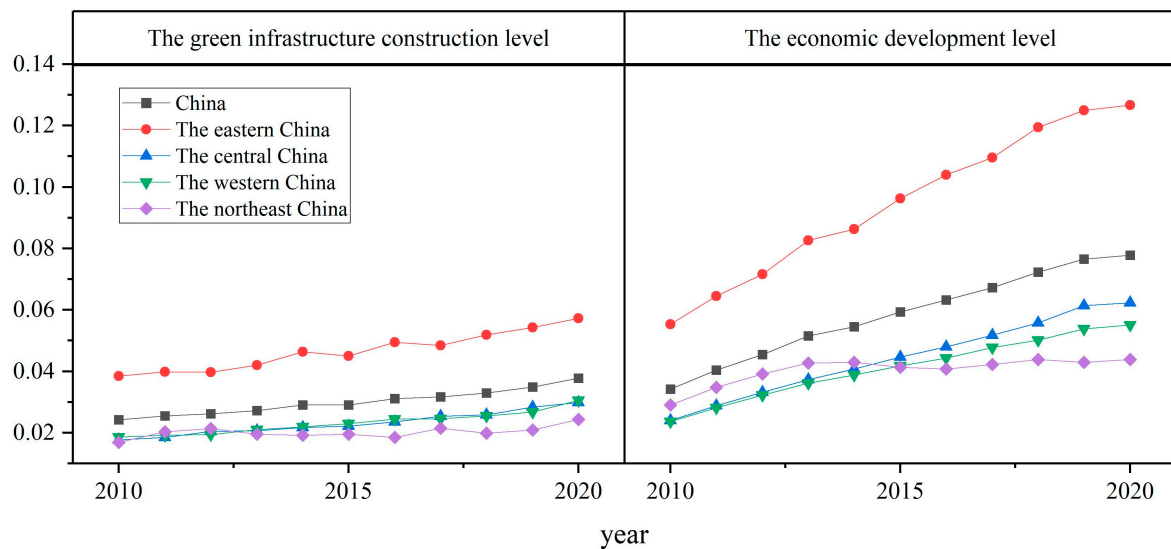


Figure 3. Temporal variation of green infrastructure construction level and economic development level in various regions of China.

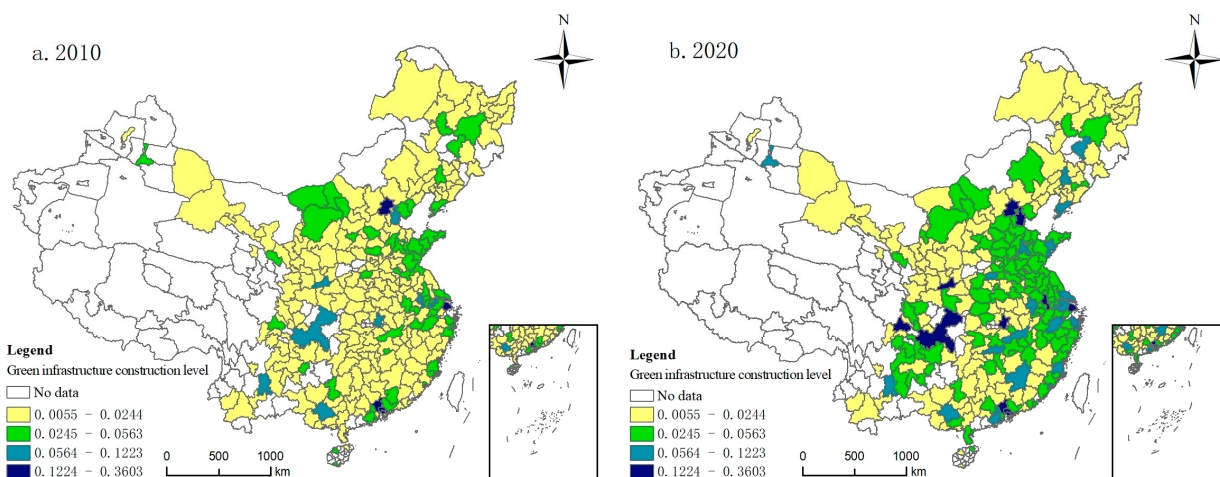


Figure 4. Spatial distribution pattern of green infrastructure construction in 2010 and 2020.

3.2. Spatial-Temporal Pattern Analysis in Economic Development

During 2010–2020, there was a consistent growth tendency and notable regional variances in China’s urban economic development (Figure 3). The national average level of urban economic development increased from 0.0342 to 0.0778. Eastern China’s economic development level grew at the quickest pace, from 0.0554 in 2010 to 0.1267 in 2020, surpassing the national average, which had the fastest growth rate from 0.0554 in 2010 to 0.1267 in 2020, exceeding the national average. The urban economic development level was also growing slightly in central and western China. The central cities were slightly ahead of the western cities. Northeastern China’s economic development level increased comparatively steadily from 2010 to 2013. By 2014, it began to stagnate and gradually lagged behind other regions.

From 2010 to 2020, the urban economic development gap in China gradually widened, and the economic development level showed a declining spatial pattern from east to west (Figure 5). There were only 18 cities in 2010 whose economic development level exceeded 0.0825 in China, of which the top three were Shanghai (0.3892), Beijing (0.3271),

and Shenzhen (0.1901). By 2020, the overall economic development level grew significantly. The first-tier cities were Shanghai (0.9168), Beijing (0.7894), and Shenzhen (0.5567). The second-tier cities were scattered in provincial capitals or important central cities like Tianjin, Wuhan, Changsha, Nanjing, Suzhou, Hangzhou, Guangzhou, Chengdu, and Chongqing. The third-tier cities were mainly clustered in Beijing–Tianjin–Hebei, Shandong Peninsula, and the Yangtze River Delta urban agglomerations in eastern coastal China and scattered in central, western, and northeastern China. There were 214 cities in the fourth tier, accounting for 78.4% of the total, indicating that regional economic development was not balanced and that there was a significant wealth gap in China.

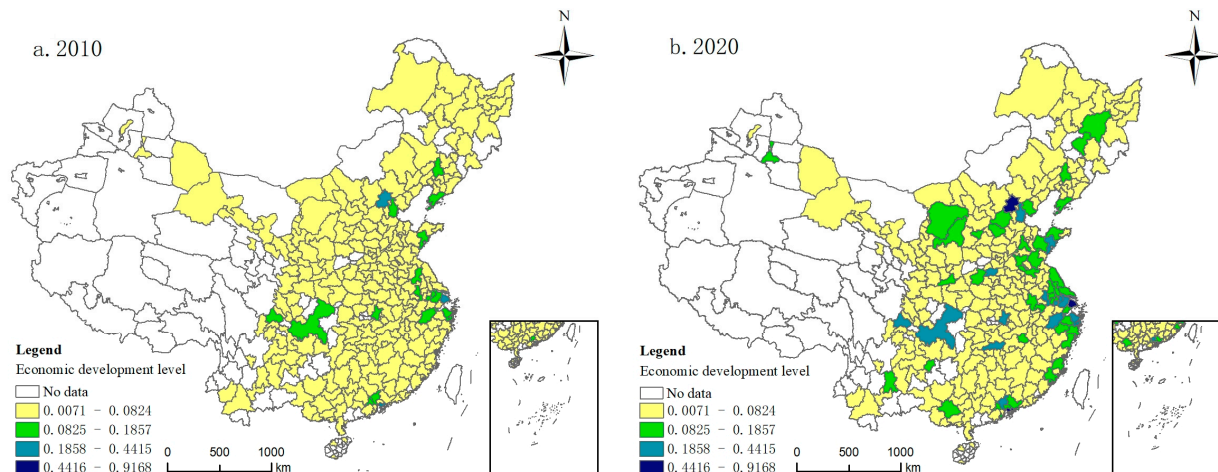


Figure 5. Spatial distribution pattern of economic development in 2010 and 2020.

3.3. Spatial-Temporal Characteristics of Coupling Coordination between Green Infrastructure Construction and Economic Development

3.3.1. Results of the Coupled Coordination Degree

The calculations found that most of the cities in China have a high degree of coupling ($0.8 < C < 1$), except for individual cities such as Quanzhou and Yulin. However, there were significant differences in the coupling coordination degree of Chinese cities, ranging from 0.09 to 0.81.

For the period 2010 to 2020, the coupling coordination degree of Chinese cities was gradually improving (Figure 6). In 2010, there were no cities with excellent coordination or moderate coordination, and the average coupling coordination degree was 0.156. Among the 273 cities, only Beijing, Shanghai, Guangzhou, and Shenzhen were marginally coordinated, and the coupling coordinated relationship between green infrastructure construction and economic growth was still in the breaking-in period. Thirty-four cities were mildly imbalanced, mainly the capital cities of various provinces, and the spatial aggregation characteristics were not significant. The seriously imbalanced cities accounted for about 86.1%. In 2012, Chongqing rose to the stage of Marginal coordination, while a small number of cities that had previously exhibited serious imbalances gradually moved towards a state of mild imbalance. In 2014, Beijing took the lead in developing moderate coordination. Tianjin and Nanjing also transformed into marginally coordinated cities. Cities that transitioned from serious imbalance to mild imbalance were mainly located in the Shandong Peninsula and Yangtze River Delta urban agglomerations. In 2016, as a national central city, Beijing took the lead in achieving excellent coordination as its economic development and green infrastructure construction grew simultaneously and developed rapidly. Shanghai had also successfully transformed itself into moderate coordination. In 2018, Beijing's economy was still growing, but investment in the construction of urban drainage and sanitation facilities was reduced, and its green infrastructure level declined and shifted to moderate coordination. In 2020, the average coupling coordination degree improved to 0.214, and the proportion of seriously imbalanced cities continued to shrink. The number of mildly

imbalanced cities continued to rise, and the scope gradually expanded from the developed urban agglomerations along China's eastern coast to the inland area.

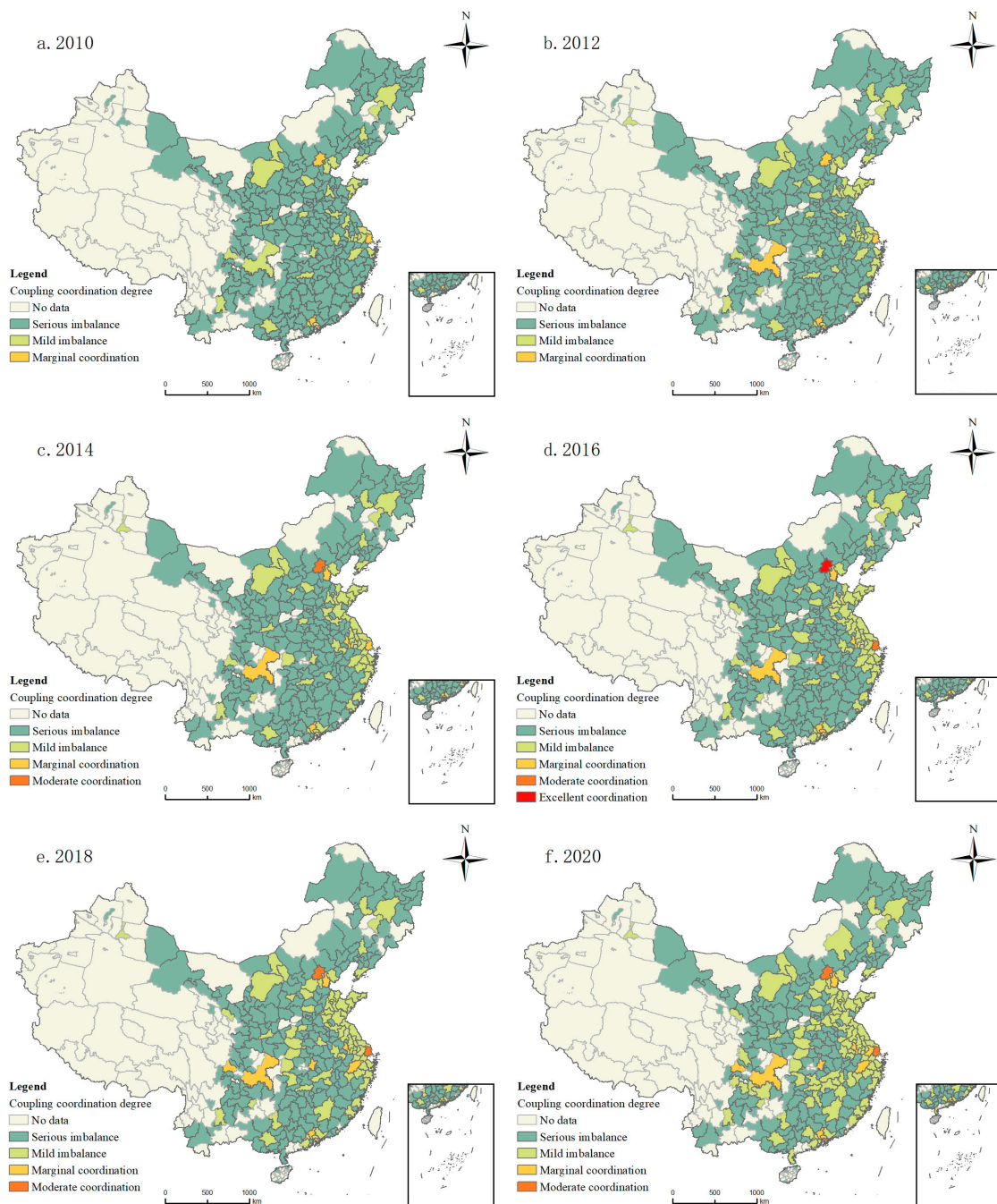


Figure 6. Spatial pattern evaluation of coupling coordination degree.

3.3.2. Dynamic Distribution of Coupling Coordination Degrees

The distribution evolution trend of the coupling coordination degree was examined using kernel density estimation. The kernel density curve (Figure 7) has only one peak and does not seem to be multipolar. The fact that the center is near the 0 side suggests that most Chinese cities have poor coupling coordination. As time goes on, the curve progressively moves to the right, and the coordination degree rises. The height drops, and the breadth expands, indicating that the differences in urban development across regions are widening. The right side of the curve is trailing, and there are individual cities with high levels of coordinated development.

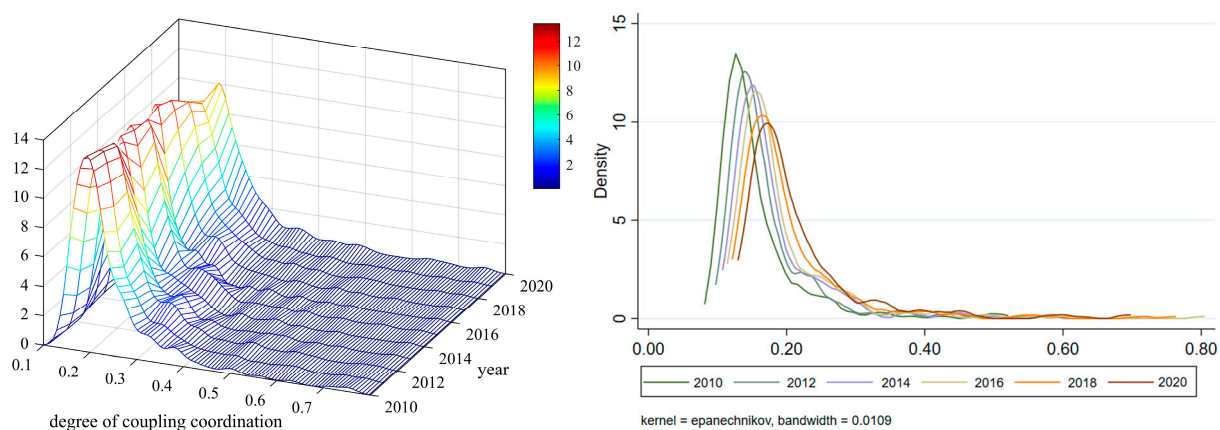


Figure 7. Kernel density curve.

3.3.3. Spatial Variation and Sources in Coupling Coordination Degrees

The overall variation in the coupling coordination degree among Chinese cities shows an upward trend, with a mean Gini coefficient of 0.180 (Table 3). Within the four major regions, there are significant geographical variations. Figure 8 shows that East China exhibits the largest internal disparity, with a mean Gini coefficient of 0.198. The overall trend of change is expanding, with initial spikes and subsequent declines, indicating that the phenomenon of imbalance in development within the region is more serious. This is followed by West and Northeast China. Their intra-regional differences in the coupling coordination degree are relatively small and decrease in fluctuation. Finally, central China has the lowest Gini coefficient, indicating that it has the smallest intra-regional differences. However, it is expanding annually, and the intra-regional difference in coupling coordination degree is increasing.

Table 3. Sources of regional variation and their contribution.

Year	Overall	Intra-Regional Gini Coefficient				Inter-Regional Gini Coefficient						Contribution Rate (%)		
		East	Central	West	Northeast	E-C	E-W	E-NE	C-W	C-NE	W-NE	Intra-Regional	Inter-Regional	Hypervariable Density
2010	0.177	0.191	0.091	0.157	0.141	0.196	0.237	0.211	0.134	0.121	0.154	23.840	46.557	29.604
2011	0.179	0.194	0.092	0.157	0.153	0.199	0.239	0.213	0.135	0.127	0.161	23.803	46.341	29.856
2012	0.176	0.192	0.099	0.152	0.153	0.193	0.230	0.206	0.135	0.131	0.158	24.139	44.606	31.255
2013	0.180	0.203	0.101	0.155	0.147	0.200	0.234	0.213	0.137	0.128	0.154	24.502	43.626	31.872
2014	0.180	0.203	0.102	0.155	0.141	0.199	0.233	0.218	0.138	0.127	0.150	24.604	43.814	31.582
2015	0.178	0.199	0.104	0.153	0.136	0.198	0.229	0.225	0.136	0.128	0.145	24.535	44.958	30.507
2016	0.182	0.202	0.107	0.154	0.131	0.201	0.232	0.239	0.137	0.133	0.145	24.472	46.903	28.625
2017	0.180	0.201	0.112	0.145	0.140	0.197	0.227	0.236	0.134	0.141	0.145	24.522	46.032	29.446
2018	0.183	0.200	0.111	0.148	0.135	0.200	0.234	0.250	0.137	0.142	0.146	24.158	48.994	26.848
2019	0.181	0.196	0.117	0.144	0.130	0.194	0.228	0.251	0.138	0.150	0.144	24.221	49.603	26.176
2020	0.182	0.196	0.115	0.147	0.137	0.195	0.228	0.252	0.137	0.151	0.149	24.154	48.057	27.789
averages	0.180	0.198	0.105	0.152	0.140	0.197	0.232	0.229	0.136	0.134	0.150	24.268	46.317	29.415

Notes: E-C is east-central; E-W is east-west; E-NE is east-northeast; C-W is central-west; C-NE is central-northeast; W-NE is west-northeast.

In terms of inter-regional Gini coefficients, E-W and E-NE had the largest inter-regional differences, with mean values of 0.232 and 0.229. E-C came next, with a mean value of 0.197. There were lesser inter-regional variations in W-NE, C-W, and C-NE. Therefore, the inter-regional variations in the coupling coordination degree were mainly driven by the inter-regional variations in E-W, E-NE, and E-C. In terms of time trends, the inter-regional Gini coefficients in E-W and W-NE showed a fluctuating downward trend, the Gini coefficients in E-C and C-W were comparatively stable, and the Gini coefficients in E-NE and C-NE were rising significantly.

The three main sources of coupling coordination degree differences contribute to a relatively stable situation, with interregional differences accounting for about 46% of overall spatial differences. The contribution rate of hypervariable density fluctuates around 29%, and the contribution rate of intra-regional differences is the lowest, at about 24%.

In Chinese cities, there has been an inconsistent degree of coupled coordination between green infrastructure construction and economic development during the period 2010–2020, mainly due to interregional differences.

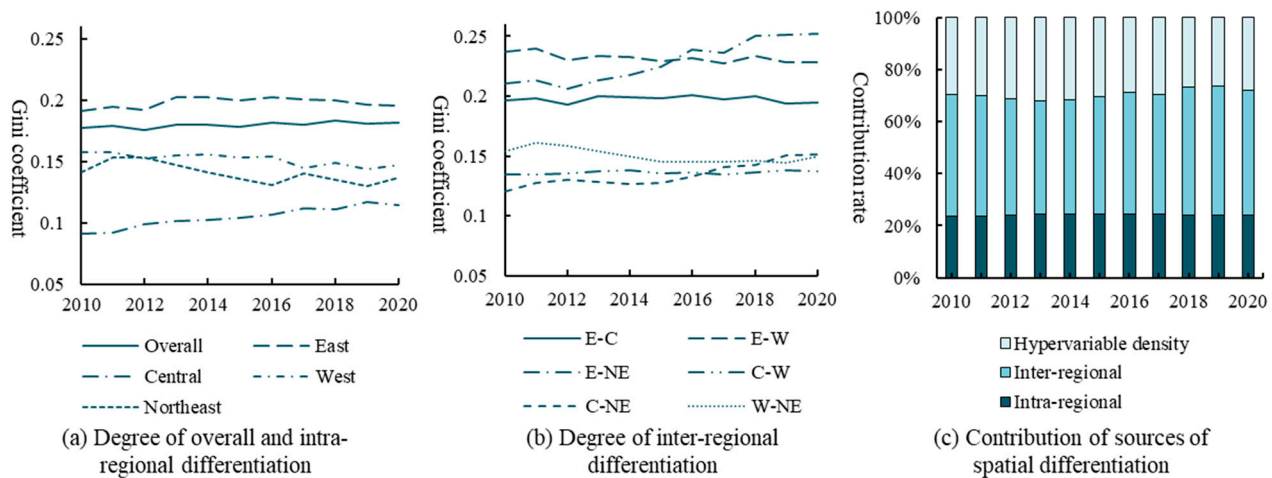


Figure 8. Spatial variation and sources of coupled coordination.

3.3.4. Spatial Correlation Characteristics of Coupling Coordination Degree

In this study, the global Moran's I value of the coupling coordination degree between urban green infrastructure construction and economic development was calculated by ArcGIS 10.6 to analyze spatial autocorrelation characteristics as a whole (Table 4). The values of the global Moran's I index for 2010–2020 were positive and passed the test of significance ($p < 0.01$). This demonstrated that there was salient positive spatial autocorrelation in the coupling coordination degree. The Moran's I value in 2010 was the largest in recent years. It gradually declined in fluctuation from 2010 to 2017, reaching a low of 0.1465, indicating that the spatial aggregation trend of the coupling coordination degree gradually attenuated during this period. It gradually increased from 2017 to 2020, and the spatial aggregation trend was slowly enhanced again.

Table 4. Global spatial autocorrelation of coupling coordination degree.

Year	Moran's I Value	z Value	p Value
2010	0.1776	7.8754	0.0000
2011	0.1726	7.6461	0.0000
2012	0.1652	7.3187	0.0000
2013	0.1773	7.8718	0.0000
2014	0.1621	7.2480	0.0000
2015	0.1685	7.5039	0.0000
2016	0.1567	7.0395	0.0000
2017	0.1465	6.5682	0.0000
2018	0.1551	6.9350	0.0000
2019	0.1595	7.1301	0.0000
2020	0.1700	7.5293	0.0000

The global spatial autocorrelation is only capable of determining whether or not the coupling coordination degree is aggregated throughout the research region and cannot reflect the local spatial correlation characteristics. There may be some cases in which the autocorrelation of some local areas is opposite to the overall autocorrelation. Therefore, this study tested and evaluated the local spatial autocorrelation of urban coupling coordination degree. Figure 9 presents a Local Indicators of Spatial Association (LISA) aggregation map of the coupling coordination degree over the years, revealing the spatial patterns of clustering and dispersion in urban coupling coordination across China.

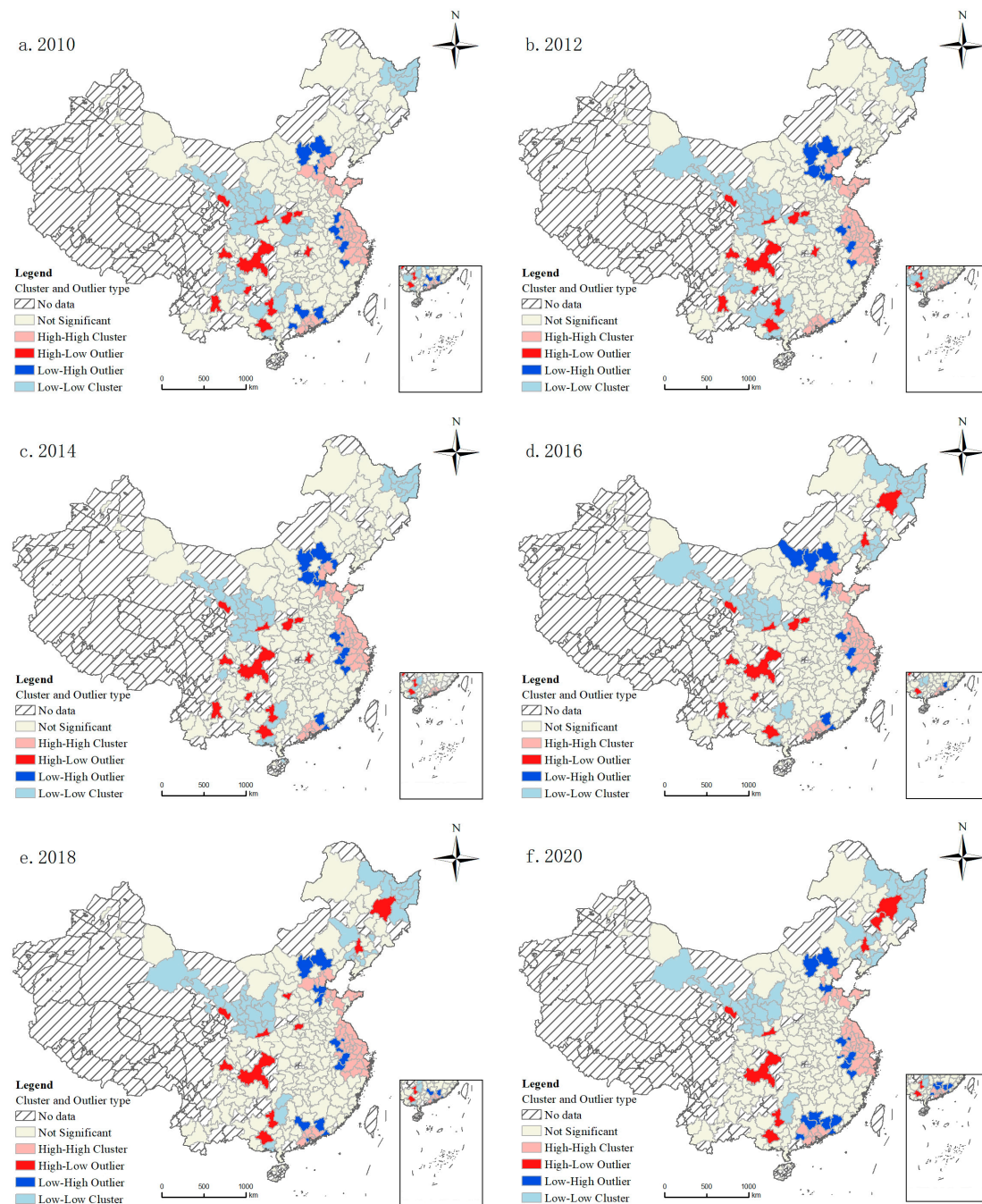


Figure 9. LISA agglomeration map of coupling coordination degree.

From 2010 to 2020, the local spatial aggregation characteristics of China's urban coupling coordination degree were remarkable. High-low outlier and low-high outlier cities were both in extremely modest numbers, while high-high cluster and low-low cluster cities predominated. In 2010, there were 40 high-high cluster cities, with the majority of them situated in eastern coastal urban agglomerations such as Beijing–Tianjin–Hebei, Shandong Peninsula, Yangtze River Delta, and Pearl River Delta. The majority of the 43 low-low cluster cities were in Northwest and Southwest China, the Three-River Plain Economic Zone, and the Central Plains Urban Agglomeration. Twelve low-high outlier cities were dispersed on the periphery of the high accumulation area, which confirmed the decreasing trend of coupling coordination degree from China's coast to inland. In central and western China, provincial capitals, including Lanzhou, Xi'an, Zhengzhou, Wuhan, Chengdu, Guiyang, Kunming, and Nanning, were among the 11 high-low outlier

cities. The types of spatial clustering did not change significantly in 2012. The low–low cluster cities in southwestern areas shrank in 2014. By 2016, 39 low–low cluster cities had been identified, and the additional cities were mainly located in Northeast China. The high–low outlier cities decreased in central and western China, such as Wuhan and Liuzhou, while it added Harbin and Shenyang in Northeast China. In 2018, Kunming and Guiyang in the southwest region were also no longer the high–low outlier cities. By 2020, the number of high–low outlier cities continued to shrink, such as Chengdu and Zhengzhou, indicating that the spatial heterogeneity of urban coupling coordination degree had steadily weakened, and regional cities had gradually developed in a balanced way in central and western China.

4. Discussion

4.1. Modeling Perspective

Urban infrastructure construction is the material basis for ensuring the normal operation and healthy development of cities. It also contributes significantly to the achievement of urban economic transformation, raises the standard of living for citizens, and reduces security threats. China once constructed extensive urban grey infrastructure, such as roads, bridges, trains, and water conservation projects, in order to prioritize achieving its economic development goals. It also reclaimed large tracts of farmland, which resulted in the destruction of some animal habitats and urban ecosystems, as well as a number of environmental pollution issues and urban diseases that made it difficult for cities to grow sustainably. In the rapid urbanization process, the traditional development path of blind expansion, low-density sprawl, and high costs urgently needs to be changed, promoting a more intensive land use pattern. Simultaneously, green infrastructure construction is another essential element in facilitating the development of cities and communities [36], and it has become a central issue in contemporary urban sustainable development. The urban economic development influences the planning of green infrastructure. The enhancement of technical proficiency and long-term upkeep are prerequisites for putting green infrastructure's functions into practice. Its administration and technical advancement demand large financial outlays [37]. Therefore, urban green infrastructure construction and economic development are part of a complex system of mutual influence and common development. There is a need to use modeling approaches to effectively assess the level of development of both as well as to better understand their interactions from a coupled perspective.

The study finally chose the entropy method to make a comprehensive evaluation of green infrastructure construction and economic development. Its advantage is that it uses an objective weighting approach to establish the indicator weight in accordance with the information supplied by data for each indicator, eliminating the subjectivity caused by subjective weighting and resulting in more accurate and effective findings. In this study, green infrastructure construction not only includes public infrastructure with ecological service functions in the city but also includes the government's financial investment in the management and maintenance of facilities, which can reasonably assess the level of green infrastructure construction. Numerous representative indicators are also chosen in the process of evaluating the level of urban economic development, including regional GDP, the percentage of tertiary industry, local general public budget revenue and expenditure, and so on. Coupling coordination degree models have been widely used to assess the interactions between multiple resources or systems [40–42]. At present, certain academics have constructed the coordination relationship model between green infrastructure and other systems, such as industrialization [29] and land use eco-efficiency [43]. This study tries to construct a coupled coordination model of urban green infrastructure construction and economic development. At the same time, the study acknowledges certain limitations and future research directions. The study's focus on China, while providing valuable context for the country's unique urban development trajectory, may not fully represent the diverse contexts and challenges faced by cities globally. Future research could consider supplementing investigations into the social dimension of sustainable development, in-

cluding the role of public participation and community engagement in green infrastructure development. This would involve exploring the intricate relationship between green infrastructure construction and both economic and social development. Conducting comparative studies across diverse regions and countries would be instrumental in understanding the varying relationships between green infrastructure and economic development, as well as identifying best practices and transferable solutions. Addressing these limitations and exploring these avenues for further research could lead to a more comprehensive understanding of the complex interplay between urban green infrastructure and economic development, ultimately contributing to more effective and equitable sustainable urban development practices globally.

4.2. Coupling Coordination Relationships between Green Infrastructure Construction and Economic Development

During 2010–2020, China's urban green infrastructure and economic development levels were both growing, mainly as a result of national efforts to promote energy conservation, reduce emissions, and implement sustainable urban development. However, it was evident that economic development was expanding more quickly across all regions and surpassing the level of green infrastructure construction. The calculations found that most of the cities in China have a high coupling degree. It demonstrates that green infrastructure construction and economic development in Chinese cities are strongly correlated, and economic development has a greater impact on green infrastructure construction [44]. At the same time, the importance of urban green infrastructure in promoting economic development should also be recognized by policymakers and practitioners. However, there were significant differences in the coupling coordination degree. Most Chinese cities have poor coupling coordination. It experienced a progressive rise in 2010–2020. The number of seriously imbalanced cities gradually decreased, and they gradually developed into mild imbalanced cities. The marginally coordinated and moderately coordinated cities were also increasing. There were significant spatial discrepancies across regions. Cities in eastern coastal China had a much higher coupling coordination degree than cities in other areas, eventually establishing a spatial structure characterized by a decreasing trend from east to west.

The urban green infrastructure construction in eastern China is developing faster than in other regions. This demonstrated that the green infrastructure construction level in areas with more advanced economic development was also higher. In eastern coastal China, the three major urban agglomerations of Beijing–Tianjin–Hebei, the Yangtze River Delta, and the Pearl River Delta had high economic development levels and strong spillover effects on neighboring cities. They also had a developed modern industrial base, a comprehensive infrastructure, and rich human resources, all of which were crucial to China's economic growth. As a result, they were taking the lead in strengthening green infrastructure construction. Cities such as Beijing, Shanghai, Guangzhou, and Shenzhen were constantly improving their green infrastructure construction while experiencing rapid economic growth. They had led the way in obtaining moderate coordination. However, compared with other eastern Chinese cities, they have developed faster and have a higher degree of coupled coordination, which has led to a gradual increase in intra-regional differences in eastern China. It may also be attributed to this that the greatest inter-regional differences are found between eastern China and the other three regions. The Central Plains Urban Agglomeration and urban agglomeration in the middle reaches of the Yangtze River, with Zhengzhou and Wuhan as their core cities, were accelerating development and had become the primary forces supporting central China's strategic rise. The western China had a weak economic foundation and a limited economic base. The Chengdu–Chongqing city cluster had been elevated to a national strategy, which was continuously promoting the financial expansion of western China. They also strived to continuously improve their economic development levels and gradually focus on green infrastructure investment and efficiency. Their coupling coordination degree gradually improved, but there was still

a certain gap with the cities in eastern coastal China. The overall economic weight in Northeast China steadily decreased as the focus of regional economic growth shifted from China's coastal port cities to inland province capitals. The level of green infrastructure construction and economic development is low and lags significantly behind other regions. The primary causes were population decline, especially the lack of young people and scientific and technological talents. Secondly, the development of advantageous industries was hindered, and the development vitality was insufficient in some resource-exhausted cities and traditional industrial and mining areas. These excessive disparities in conditions, such as the economic environment, were gradually extending the inter-regional differences in urban coupling coordinated development in east–northeast and central–northeast. It also confirms that the sluggish economic development in Northeast China had a certain impact on urban green infrastructure construction.

The coupling coordination degree showed a noticeable positive spatial autocorrelation. In other words, cities that possessed higher coupling coordination degrees tended to agglomerate development. The local spatial aggregation characteristics of China's coupling coordination degree were very significant during 2010–2020. The urban agglomerations in eastern coastal China, such as Beijing–Tianjin–Hebei, Shandong Peninsula, Yangtze River Delta, and Pearl River Delta, were always in the high–high cluster area. The low–low cluster cities were mostly situated in China's central, western, and northeastern areas. Meanwhile, there was also a certain amount of spatial heterogeneity within the region. As the economic and political centers of the provinces, the provincial capital cities in central and western China had more development opportunities and had a higher degree of coupling coordination compared to neighboring cities, so they showed spatial heterogeneity. Spatial heterogeneity was diminishing over time and these cities were gradually developing in a balanced way. However, the opposite was true for Northeast China, where their spatial heterogeneity gradually increased. Harbin, Shenyang, and Changchun were the core cities of the three Northeast China provinces. Their green infrastructure construction and economic development were more synchronized and had a relatively high coupling coordination degree. However, their spillover effect was insufficient, and the neighboring cities still lagged in development, resulting in a local polarization effect. Ultimately, the research validates that despite the continuous development and coordinated expansion of Chinese cities throughout all regions, there are still enormous disparities in urban policies, investments, institutions, resources, and other aspects. These all have an impact on how green infrastructure construction and economic development are coupled and coordinated. China's entire level of coupling coordination degree still has much room for improvement. The regional disparity needs to be broken down, and regional spatial coordination should be strengthened.

Developed countries like the United States, which build green spaces, greenways, and gardens in their cities, have considered green infrastructure as a key strategy for improving urban sustainability [45]. As federal, state, and local governments incorporate green infrastructure into their infrastructure plans, it not only provides stormwater management and well-being benefits but also creates jobs and adds value to the regional economy at a scale comparable to established industries [25]. However, Wong, SM [46] found that the annual maintenance cost of green infrastructure in New York City exceeded its annual economic value, resulting in a long investment payback period. This highlights the need to carefully consider economic, social, and environmental aspects when implementing green infrastructure projects. In countries with limited space, such as Norway, Denmark, Sweden, and the UK, innovative approaches have emerged. Instead of constructing new parks and green spaces, they are integrating vegetation into existing infrastructure through green walls, green roofs, and street trees. This offers valuable lessons for China, demonstrating the potential for flexible and space-efficient green infrastructure strategies. Mature economies with strong sustainability commitments, like Germany and Sweden, often place a greater emphasis on green infrastructure investment and its integration with economic development, providing valuable lessons for China. However, many developing nations

are still in the early stages of adopting green infrastructure concepts and practices. In rapidly developing economies like India or Brazil, the coupling coordination relationship between green infrastructure and economic development might differ due to variations in economic structures, urbanization rates, and environmental regulations. For instance, in the Sao Paulo Macrometropolis, Brazil, the uneven allocation of funds for infrastructure projects across different cities has led to environmental injustices regarding green and blue infrastructure. To address this, research suggests promoting sustainable tourism development and providing financial incentives for environmental protection, fostering sustainable development among municipalities [47]. Discussions of the study for Pakistan found that the economic and environmental benefits of green infrastructure far outweigh its construction costs and operating expenses [48]. The primary reason for choosing green infrastructure for investment is that it can help the economic growth process. The growth rate in emerging and developing economies was higher at 5.4 percent in 2015 as compared to 2.3 percent in developed economies in the same year [49]. This highlights the potential of green infrastructure to contribute significantly to economic and social progress in developing nations. These international case studies demonstrate the development of green infrastructure construction and its relationship to economic growth, highlighting the need for tailored strategies based on local contexts. By learning from the experiences of both developed and developing nations, China can refine its own approach to green infrastructure development, fostering a sustainable and prosperous future.

4.3. Policy Implications

From the evaluation results of China's urban green infrastructure construction level, the investment in urban municipal infrastructure accounts for a larger weight. In order to support urban green infrastructure and promote its coordinated development with economic growth, the government should increase the investment in urban green infrastructure construction, encourage private capital participation in investment, and adopt preferential policies, tax policies, and other ways.

Based on the advantages of regional resources and location conditions, cities in various regions should rationalize urban green infrastructure construction and promote the coordinated development of urban economic growth, green infrastructure construction, and ecological environmental protection. Some heavy industrial cities in Northeastern China have experienced delayed economic transformation, but their high-quality natural resources, such as forests and water sources and the manufacturing base, are crucial advantages for the development of a green economy in the future. These cities should focus on accelerating the digital, networked, and intelligent transformation of traditional manufacturing industries, developing soft power industries with fewer cost inputs and shorter payback cycles, and expanding the scale of urban green infrastructure in order to accomplish mutual economic growth and environmental improvement.

Mechanisms for synergistic development between regional cities can be established. The coupling coordination degree of China's eastern coastal cities has always been in the high-high cluster area. While continuing to promote their leading position in coordinated development, these cities can support central and western China in achieving synergy between green infrastructure and economic development through technology, capital, and other factors. The high-low outlier cities in central China, including Zhengzhou, Wuhan, Chongqing, Chengdu, and so on, while accelerating their construction development and forming agglomeration centers, should take the lead in spearheading the development of neighboring cities and integrating and optimizing cross-regional resources. Special coordination agencies can be set up to promote information sharing and cooperation among cities, help coordinate resources in various regions, and complete green infrastructure projects. It helps to form a long-term cooperative relationship and then narrow the geographic disparities in the coupling coordination of green infrastructure construction and economic development.

5. Conclusions

The study investigated spatial-temporal pattern characteristics of urban green infrastructure construction level and economic development level of 273 cities in the Chinese mainland in 2010–2020 by constructing the evaluation indicator system and assessed spatial differences and evolutionary trends in their coupling coordination relationships. The following are the primary conclusions:

- (1) The entire level of China's urban green infrastructure construction and economic development was gradually increasing from 2010 to 2020. The national average level of green infrastructure construction had risen from 0.024 to 0.038. Urban economic development level also increased from 0.034 to 0.078. There were obvious regional differences, displaying a declining spatial pattern from east to west. China's eastern coastal developed cities and inland core cities had rapid economic development, and their green infrastructure construction level was relatively high.
- (2) From 2010 to 2020, the coupling coordination degree between China's urban green infrastructure construction and economic development gradually increased from 0.156 to 0.214. Regional disparities in space were apparent, and it was easy to observe how spatial patterns had changed through time. The seriously imbalanced cities had a higher proportion in China, but the number was gradually decreasing, as some of them were slowly transformed into mild imbalances throughout the research period. The number of marginally coordinated and moderately coordinated cities was less, and it was also increasing year by year. Cities in eastern coastal China had a much higher coupling coordination degree than cities in other areas, eventually establishing a spatial structure characterized by a decreasing trend from east to west.
- (3) The overall variation in the coupling coordination degree among Chinese cities shows an upward trend, with a mean Gini coefficient of 0.180. Among the four regions, the eastern China has the greatest intraregional variation. The uneven level of coupled coordination is mainly from interregional differences. However, there are relatively large inter-regional differences in east–west, east–northeast, and east–central.
- (4) There was a significant positive spatial autocorrelation relationship in the coupling coordination degree. Cities that had a higher degree of coupling coordination tended to agglomeration development. The local spatial correlation test demonstrated significant spatial aggregation, and high–high cluster and low–low cluster cities were dominant. The high–high cluster area consistently covered the urban agglomerations in eastern coastal China, such as Beijing–Tianjin–Hebei, Shandong Peninsula, Yangtze River Delta, and Pearl River Delta, whereas the low–low cluster cities were mostly situated in China's central, western, and northeastern areas. At the same time, there was also a certain amount of spatial heterogeneity within the region, and it was gradually weakening. Cities in central and western China were gradually developing in a balanced way. China's entire level of coupling coordination degree still has much room for improvement. The regional disparity needs to be broken down, and regional spatial coordination should be strengthened.

Author Contributions: Conceptualization, W.W.; data curation, W.W.; formal analysis, W.W.; investigation, W.W.; methodology, W.W.; resources, W.W.; validation, W.W.; visualization, W.W.; writing—original draft, W.W.; writing—review and editing, W.W., Y.W., W.C. and Y.Q. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported in part by the National Natural Science Foundation of China (No. 42001187).

Data Availability Statement: The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

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

References

- Wu, W.; Fu, X.E. The concept of green infrastructure and review of its research development. *Urban Plan. Int.* **2009**, *24*, 67–71.
- Luan, B.; Chai, M.W.; Wang, X. Review of development, frontiers, and prospects of green infrastructure. *Acta Ecol. Sin.* **2017**, *37*, 5246–5261.
- Young, R.; Zanders, J.; Lieberknecht, K.; Fassman-Beck, E. A comprehensive typology for mainstreaming urban green infrastructure. *J. Hydrol.* **2014**, *519*, 2571–2583. [\[CrossRef\]](#)
- Wang, Y.H.; Li, C.L.; Wang, H.; Liang, B.M.; Lv, J.S. Current status and hotspots of research in the field of ecology and environment of green infrastructure. *Acta Ecol. Sin.* **2022**, *42*, 2510–2521.
- Benedict, M.A.; McMahon, E.T. *Green Infrastructure: Linking Landscapes and Communities*; Island Press: Washington, DC, USA, 2012.
- Shen, Q.J. Introduce and discuss on A Guide to Green Infrastructure for Canadian Municipalities. *Urban Plan. Forum.* **2005**, *5*, 102–107.
- Liberalesso, T.; Cruz, C.O.; Silva, C.M.; Manso, M. Green infrastructure and public policies: An international review of green roofs and green walls incentives. *Land Use Policy* **2020**, *96*, 104693. [\[CrossRef\]](#)
- Ying, J.; Zhang, X.J.; Zhang, Y.Q.; Bilan, S. Green infrastructure: Systematic literature review. *Econ. Res. Ekon. Istraz.* **2022**, *35*, 343–366. [\[CrossRef\]](#)
- Hewitt, C.N.; Ashworth, K.; MacKenzie, A.R. Using green infrastructure to improve urban air quality (GI4AQ). *Ambio* **2020**, *49*, 62–73. [\[CrossRef\]](#) [\[PubMed\]](#)
- Meerow, S.; Newell, J.P. Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit. *Landsc. Urban Plan.* **2017**, *159*, 62–75. [\[CrossRef\]](#)
- Morozova, G.Y.; Debelaya, I.D. Green Infrastructure as a Factor for Sustainable Development of Khabarovsk. *Ekon. Reg. Econ. Reg.* **2018**, *14*, 562–574. [\[CrossRef\]](#)
- Qiu, Y.; Chang, Q.; Wang, J. A MSPA-based planning of urban green infrastructure network—A case of shenzhen. *Chin. Landsc. Archit.* **2013**, *29*, 104–108.
- An, C.; Shen, Q.J. Method of constructing network of green infrastructure based on ecological performance of space utilization. *Landsc. Archit.* **2013**, *2*, 22–31. [\[CrossRef\]](#)
- Weber, T.; Sloan, A.; Wolf, J. Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. *Landsc. Urban Plan.* **2006**, *77*, 94–110. [\[CrossRef\]](#)
- Wang, Y.Z.; Li, J.L.; Gu, K.K.; Lu, L. Optimization of urban green infrastructure network layout based on MSPA- CIRCUIT: Case of Hefei. *Acta Ecol. Sin.* **2022**, *42*, 2022–2032.
- Zhao, H.X.; Fan, J.D.; Luo, X.L.; Zhu, T.Y.; Meng, F. Changes of green infrastructure pattern and its driving factors: Taking Nanjing as an example. *Acta Ecol. Sin.* **2022**, *42*, 7597–7611.
- Zheng, W.; Barker, A. Green infrastructure and urbanisation in suburban Beijing: An improved neighbourhood assessment framework. *Habitat Int.* **2021**, *117*, 102423. [\[CrossRef\]](#)
- Liu, W.P.; Holst, J.; Yu, Z.R. Thresholds of landscape change: A new tool to manage green infrastructure and social-economic development. *Landsc. Ecol.* **2014**, *29*, 729–743. [\[CrossRef\]](#)
- Cui, Y.; Jia, Y.C.; Sun, Y. The coordinated relationship of industrialization, environmental carrying capacity and green infrastructure—Taking tianjin as an example. *City* **2021**, *6*, 3–14.
- Gao, M. Urban green infrastructure and ecological environment protection. *Environ. Dev.* **2018**, *30*, 181–183. [\[CrossRef\]](#)
- Li, J.Y.; Zhan, S.; Jin, B.F. The direct impact of rural green infrastructure on economic growth and its spatial spillover effect. *Hebei Financ.* **2022**, *5*, 7–14. [\[CrossRef\]](#)
- Mell, I.C.; Henneberry, J.; Hehl-Lange, S.; Keskin, B. Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. *Urban For. Urban Green.* **2013**, *12*, 296–306. [\[CrossRef\]](#)
- Vandermeulen, V.; Verspecht, A.; Vermeire, B.; Van Huylenbroeck, G.; Gellynck, X. The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landsc. Urban Plan.* **2011**, *103*, 198–206. [\[CrossRef\]](#)
- Fu, X.E.; Qian, D.; Han, L.B.; Zhang, K.Y. Research on the benefit evaluation of urban green infrastructure based on total economic value. *Constr. Econ.* **2015**, *36*, 83–86. [\[CrossRef\]](#)
- Galvin, E.M.; Bendor, T.K. The economic impacts of green stormwater infrastructure: An evaluation of novel stormwater management policies in Washington, DC. *Land Use Policy* **2023**, *134*, 106915. [\[CrossRef\]](#)
- Mell, I.C.; Henneberry, J.; Hehl-Lange, S.; Keskin, B. To green or not to green: Establishing the economic value of green infrastructure investments in The Wicker, Sheffield. *Urban For. Urban Green.* **2016**, *18*, 257–267. [\[CrossRef\]](#)
- Zhou, Q.; Shi, W.; Guo, Q.H. The influential mechanism of urban environmental and green infrastructure Investments on urban high quality economic growth. *Acta Ecol. Sin.* **2021**, *41*, 8820–8832.
- He, M.W.; Ge, D.Y.; Jiang, J.Y.; Wang, P.C.; Yao, C.H. How do urban function and development level effect construction level of green infrastructure? A case study of 110 built-up areas of cities in the Yangtze River Economic Zone. *Cities* **2023**, *143*, 104620. [\[CrossRef\]](#)
- Cui, Y. The coordinated relationship among industrialization, environmental carrying capacity and green infrastructure: A comparative research of Beijing-Tianjin-Hebei region, China. *Environ. Dev.* **2022**, *44*, 100775. [\[CrossRef\]](#)
- Zhang, F.; Wang, X.T.; Liu, X.J. Research on Functional Value Estimation and Development Mode of Green Infrastructure Based on Multi-Dimensional Evaluation Model: A Case Study of China. *Land* **2022**, *11*, 1603. [\[CrossRef\]](#)

31. Peng, B.H.; Sheng, X.; Wei, G. Does environmental protection promote economic development? From the perspective of coupling coordination between environmental protection and economic development. *Environ. Sci. Pollut. Res.* **2020**, *27*, 39135–39148. [\[CrossRef\]](#)
32. Kong, F.X.; Liu, X.Z.; Zhou, H.M.; He, Q. Spatio-temporal evolution characteristics and influencing factors of the coupling coordination between new infrastructure construction and urban green development. *Econ. Geogr.* **2022**, *42*, 22–32. [\[CrossRef\]](#)
33. Li, Q.; Li, S.L.; Bai, X.; Xia, T.; Chen, X.L. Spatio-temporal characteristics of the coupling and coordination of Guangdong-Hong Kong-Macau Greater Bay Area's basic public services and economic development. *Prog. Geogr.* **2022**, *41*, 1688–1701. [\[CrossRef\]](#)
34. Fang, S.M.; Huang, Y. Spatio-temporal evolutions and coordination of tourism efficiency and scale in the Yangtze River Economic Belt. *Acta Geogr. Sin.* **2020**, *75*, 1757–1772.
35. Wang, C.; Tang, N. Spatio-temporal characteristics and evolution of rural productionliving-ecological space function coupling coordination in Chongqing Municipality. *Geogr. Res.* **2018**, *37*, 1100–1114.
36. Zhang, W.; Zhou, Y.; Hu, G.W. Coupling mechanism and space-time coordination of new-approach urbanization, new-approach industrialization and service industry modernization in megacity behemoths: A case study of ten cities in china. *Sci. Geogr. Sin.* **2013**, *33*, 562–569. [\[CrossRef\]](#)
37. Liu, Y.B.; Li, R.D.; Song, X.F. Coupling degree analysis of urbanization and ecological environment in China. *J. Nat. Resour.* **2005**, *1*, 105–112.
38. Cheng, S.L.; Yu, Y.; Fan, W.; Zhu, C.X. Spatio-Temporal Variation and Decomposition Analysis of Livelihood Resilience of Rural Residents in China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 10612. [\[CrossRef\]](#) [\[PubMed\]](#)
39. Liang, X.D.; Li, J.C.; Guo, G.X.; Li, S.P.; Gong, Q.X. Urban water resource utilization efficiency based on SBM-undesirable-Gini coefficient-kernel density in Gansu Province, China. *Environ. Dev. Sustain.* **2023**, *25*, 13015–13034. [\[CrossRef\]](#)
40. Sun, X.S.; Tao, J.; Kuang, X.M. A study of industrial structure, government attention, and coupling coordination of digital-green economy in China. *J. Environ. Plan. Manag.* **2023**. [\[CrossRef\]](#)
41. Wu, Q.; Hong, S.; Yang, L.; Mu, H.; Huang, C.Q.; Niu, X.X.; Zhong, Y.M.; Yi, J.H.; He, C. Coupling coordination relationships between air pollutant concentrations and emissions in China. *Atmos. Pollut. Res.* **2023**, *14*, 101678. [\[CrossRef\]](#)
42. Qi, Y.Y.; Farnoosh, A.; Lin, L.; Liu, H. Coupling coordination analysis of China's provincial water-energy-food nexus. *Environ. Sci. Pollut. Res.* **2022**, *29*, 23303–23313. [\[CrossRef\]](#)
43. Ma, Y.; Zheng, M.R.; Xu, F.; Qian, Y.; Liu, M.L.; Zheng, X.Q.; Liu, J.T. Modeling and exploring the coordination relationship between green infrastructure and land use eco-efficiency: An urban agglomeration perspective. *Environ. Sci. Pollut. Res.* **2023**, *30*, 92537–92554. [\[CrossRef\]](#)
44. Wang, R. Fuzzy-based multicriteria analysis of the driving factors and solution strategies for green infrastructure development in China. *Sustain. Cities Soc.* **2022**, *82*, 103898. [\[CrossRef\]](#)
45. Culligan, P.J. Green infrastructure and urban sustainability: A discussion of recent advances and future challenges based on multiyear observations in New York City. *Sci. Technol. Built Environ.* **2019**, *25*, 1113–1120. [\[CrossRef\]](#)
46. Wong, S.M.; Montalto, F.A. Exploring the Long-Term Economic and Social Impact of Green Infrastructure in New York City. *Water Resour. Res.* **2020**, *56*, e2019WR027008. [\[CrossRef\]](#)
47. Amaral, M.H.; Benites-Lazaro, L.L.; Sinisgalli, P.A.D.; Alves, H.P.D.; Giatti, L.L. Environmental injustices on green and blue infrastructure: Urban nexus in a macrometropolitan territory. *J. Clean. Prod.* **2021**, *289*, 125829. [\[CrossRef\]](#)
48. Babar, A.H.K.; Ali, Y.; Gohar, A. Economic and environmental impact of green infrastructures on developing economies: Pakistan a case in point. *Nat. Resour. Forum* **2024**. [\[CrossRef\]](#)
49. Chen, J.; Rojniruttikul, N.; Kun, L.; Ullah, S. Management of Green Economic Infrastructure and Environmental Sustainability in One Belt and Road Initiative Economies. *Environ. Sci. Pollut. Res.* **2022**, *29*, 36326–36336. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.