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Coupling and Spatial Disparities of Regional Economy and Ecosystem in High-Quality Town Development

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ABSTRACT

This study investigates the coordination between regional economic growth and ecological sustainability within the context of high-quality town economy development. To address the challenges of balancing economic expansion with environmental protection, a comprehensive evaluation index system is constructed, encompassing two key dimensions: regional economy and ecological environment. Using panel data from 2013 to 2022, the coupling coordination degree model is employed to quantify the interactions and synergy between these dimensions. Additionally, spatial econometric methods are applied to calculate both global and local Moran's Index, revealing spatial clustering patterns, regional disparities, and heterogeneity. The relative development model further identifies critical factors influencing regional coordination, with a focus on the lagging development of basic infrastructure and public services. The findings demonstrate a positive temporal trend toward improved regional coordination and reduced development gaps, with a spatial pattern characterized by higher coupling degrees in eastern and central regions compared to western areas. Based on these results, this study proposes actionable strategies to enhance coordinated development, emphasizing ecological conservation, the establishment of green production and consumption systems, ecological restoration, and strengthened municipal collaboration.This revised abstract emphasizes the study's purpose, methods, and key findings more clearly while maintaining a professional and concise tone. Finally, based on the above analysis results, the corresponding coordinated development suggestions of regional economy and ecological environment are given from the aspects of ecological environment protection measures, green production

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and consumption system construction, ecological environment restoration and municipal coordination.

Keywords: Regional Economies; Ecological Environment; Coupling Coordination Degree; Spatiotemporal Distribution Characteristics; Relative Development Model

1. Introduction

In the new journey of promoting coordinated development among regions across the country, it has become an important strategic guidance for national development in the new era to balance economic development and environmental protection and achieve the goal of green and sustainable development. The policy framework at the national level clearly points out that the regional coordinated development strategy should be thoroughly implemented and the regional development layout should be optimized, aiming to build a new regional development model that both promotes economic growth and ensures ecological security[1].

With the rapid advancement of urbanization, urban areas have gradually become the central regions for social life and economic production[2]. However, beyond the imperfections in China's policy system and economic institutional flaws, the excessive spatial concentration of local human activities has led to severe urban congestion, air pollution, traffic jams, and ecological degradation[3]. These factors may also indirectly cause various unpredictable problems or challenges, making it difficult to achieve coordinated regional development[4]. In the broad consensus on the coordinated development of Chinese cities, analysing the coordinated development level and spatial distribution of a specific city in China can help understand the effectiveness of urban coordination and provide valuable insights for the coordinated development of other cities

Across the country, the level of economic development and ecological environment varies significantly among different regions[5]. Therefore, in the process of promoting regional coordinated development, it is necessary to fully consider the resource endowment, environmental capacity and development stage of each region, and formulate differentiated regional development strategies. This requires that while developing the economy, we should pay more attention to the protection and restoration of the ecological environment and promote the formation of a green development mode and lifestyle.

Currently, Chinese scholars have begun to explore the coordinated development of urban and rural regions, but their research primarily focuses on the impact of specific aspects on regional coordination. There is relatively little research that analyses the coupling coordination and regional heterogeneity at the urban-rural level within China[6]. In order to achieve this goal, the whole country needs to jointly build a multi-dimensional comprehensive evaluation system including industrial development, infrastructure construction, public service supply, ecological and environmental protection and other aspects. Quality economy based on the background of the town quality development, build five comprehensive evaluation systems of high-quality development, introduce the coupling coordination degree model of industrial development, infrastructure, public service, green beauty of the ecological coupling, in this system, the ecological environment protection is placed in the equally important position and economic development, through the introduction of air quality index, surface water reaches optimal index, and put forward relevant suggestions, encourage all regions in the pursuit of economic growth at the same time, actively adopt the ecological friendly development path.

2. Literature Review

Banner (1999), Acuto (2018), and Zhang and Wang (2018) argue that regional development imbalances are one of the prominent issues in China's socio-economic development, affecting the sustainability of social and economic growth[7–9]. This is also a common problem in the development of countries worldwide. Storper (2018) believes that due to various factors such as geographical location, climatic conditions, historical reasons, and policy influences, it is difficult to maintain balanced development between regions, leading to a gradual widening of regional development gaps[10]. Under the background of the new era, ecological environment pollution and resource depletion and other ecological and environmental problems have become a major factor restricting the urban development, and how to realize

the coordinated development of urban economy and ecological environment has become one of the focuses of social attention. Wang (2020) proposed that the public, enterprises, and the country should accelerate the adjustment, transformation, upgrading and optimization of industrial structure, and promote the coordinated development of regional economy and ecological environment[11].

In the quantitative measurement of regional coordinated development, various methods have been employed in the academic field. For instance, Chen et al. (2004) and Chen et al. (2020) use the Gini coefficient, Wei (1992) employs the relative deviation coefficient, Qin et al. (2011) utilize the coefficient of variation, Zhao (2024) uses the center of gravity model, spatial dislocation index model, spatial variance model and obstacle model, etc.[12–16]. When it comes to mechanism innovation for promoting regional coordinated development in the new phase, scholars typically use indicator systems to comprehensively assess the differences in coordinated development among different regions. Among the various evaluation indicators, Ding et al. (2020) and Li et al. (2023) suggest that economic development disparities are generally considered the foundation for quantitative analysis of regional coordinated development[17, 18]. Multiple studies based on spatial economics often use economic and industrial indicators as standards to measure development differences between regions, highlighting the changes in the coordination levels among the eastern, central, western, and northeastern regions of China. In addition, Wu et al. (2003) and Lee (2024) believe that the ecological environment and other indicators have gradually become the new direction of regional coordinated development[19, 20]. Yang (2024) found that the level of external development, environmental governance and infrastructure are the main factors affecting the coupling and coordination level between regional economy and ecological environment[21]. Sun et al. (2024) posit that coordinating regional ecological environmental interests primarily involves balancing the interests between different areas within and outside the scope of ecological governance, and that an eco-compensation mechanism and the promotion of regional communication serve as the natural and harmonious underpinnings for achieving regional coordinated development. Lee et al. (2024) argue that urban ecological resilience is now a significant metric for assessing the extent of urban ecological advancement and it plays a critical role in promoting coordinated regional development[22].

For the construction of the coordinated development of economic and ecological environment index system, academic methods including Li (2015) using factor analysis of the coordinated development coefficient of economic and environmental system, and evaluating the coordinated development of the two systems, Li (2015) using pressure-state-response model, build the coastal area economic and environmental coordinated development evaluation index system, Gao (2017) using the combination of quantitative and qualitative hierarchical analysis to determine the index weight and establish the index system, etc.[23–25]. Based on the above methods, on the basis of the existing evaluation index system of regional coordinated development, this paper constructs the index system of coordinated development of economy and ecological environment from the two systems of regional economy and ecological environment, involving many aspects such as industrial development, infrastructure, public service and green ecology.

Li and Yi (2020) suggest that Coupling Theory can be used to describe the degree of interaction between two or more systems[26]. By employing the Coupling Coordination Degree Model (CCDM) to calculate the coupling degree and coupling coordination degree, the model reflects the extent of interaction and coordination between systems, thereby assessing whether these systems are developing harmoniously. Scholars typically construct corresponding indicator systems and evaluation methods to measure the levels of economic, environmental, and social composite systems, and then use the coupling coordination degree model to assess the level of coordinated development. In the study of economic, environmental, social, and ecological coupling coordination, Zhao et al. (2017) focused on the national level, Cheng (2018) and Hu and Xu (2020) studied the provincial level, while Sun and Cui (2018), Xing et al. (2019), and Pan et al. (2020) conducted research at the city level[27–31].

At present, the Moran's I is generally used to analyze the spatial correlation of regions. Wang et al. (2024) utilized a spatial econometric model to analyse the spatial-temporal distribution characteristics of coupling degrees in their study of regional coordinated development[32]. The global Moran's coefficient is used to describe the spatial aggregation characteristics and distribution patterns of the entire study area, while the local Moran's coefficient analyses the features of

regional heterogeneity. A relative development model was also used to more visually analyze the impact of environmental lags on quality development. Lee et al. (2024) also used Moran's I to analyze the spatial aggregation effect of research objects when studying spatial correlation [33].

Based on this, referring to the study of Chu et al. (2024), this paper uses the comprehensive evaluation model, coupled coordination model and spatial autocorrelation analysis when studying the degree of regional economic and ecological coupling coordination and their spatial and temporal differences [34]. Existing studies on regional coordinated development predominantly focus on either economic growth or environmental preservation, often neglecting the interplay and regional disparities within the context of high-quality town economy development. This study innovatively integrates the coupling coordination model with spatial autocorrelation to capture both the temporal dynamics and spatial heterogeneity of economic-ecological interactions, thereby providing a novel framework for analyzing regional disparities and their driving factors.

3. Research Methodology and Data Sources

3.1. Construction of an Integrated Rating System

Following the principles of combining integrity, completeness and scientificity, operability and practicability, and universality and particularity, this paper builds an index system of the coordinated development of economy and ecological environment from the existing evaluation index system of regional economy and ecological environment. The coordinated development of regional economy and ecological environment is a complex and comprehensive process, involving industrial development, infrastructure, public services, green ecology and other aspects. When formulating the basis for index selection, it is necessary to consider the guiding ideology and specific policy measures of the Chinese government policies in the corresponding aspects, so as to realize the regional coordinated development strategy and the development goals mentioned in the "millions of projects", namely, the new pattern of regional coordinated development of industrial coordination, facility exchange, service sharing and environmental protection.

First, we divide the coordinated economic development into three parts: industrial development, infrastructure construction and public services.In terms of industrial development, the Chinese government's plans and the 2035 long-term goals emphasize the optimization and upgrading of the industrial structure, promoting the development of modern services and high-end manufacturing industries. Therefore, when selecting industrial development indicators, factors such as industrial structure optimization, technological innovation, and market demand should be considered to facilitate the transformation and upgrading of the regional economy. The selection of industrial development indicators in this study references the research of Ding et al. (2020) and Li et al. (2023), which cover aspects such as GDP, public budget, retail consumption, taxation, household income, gross industrial output, import and export, and urbanization. These scholars suggest that economic development disparities are typically regarded as the foundation for quantitative analysis of regional coordinated development.

Secondly, we set the index of the coordinated development of ecological environment regions as green and beautiful ecology. Ecological management is a crucial pillar for achieving sustainable regional development. The Chinese government's reports emphasize the need to strengthen ecological governance, specifically including reducing pollution levels, controlling air quality indicators like fine particulate matter, and restoring forest ecosystems. Therefore, when selecting indicators, it is important to consider aspects such as the area of protected ecological zones, environmental quality, and resource utilization efficiency to ensure a positive cycle between economic development and the ecological environment. Referring to the study by Chu C. C. et al. (2023) on green urban development in China and taking into account the ecological situation in Foshan, this paper selects indicators such as the air quality index, the proportion of surface water meeting quality standards, greening coverage rate, nitrogen dioxide concentration, acid rain, inhalable particulate matter, and PM2.5 as measures of green and beautiful ecology [35].

In summary, the selection of economic and ecological coordinated development indicators covers industrial development, infrastructure construction, public services and green and beautiful ecology, which not only considers the guiding ideology of central policies, but also takes into account specific policies and measures. Through scientific and

reasonable formulation of index selection basis, regions can be better guided to coordinated development and the gap between urban and rural areas can be reduced.

3.2. Research Method

3.2.1. Comprehensive Evaluation Model

According to the above analysis basis, based on the high-quality development of town economy, this study constructs a comprehensive evaluation index system of the coordinated development level of economy and ecological environment composed of industrial development, infrastructure, public service and green and beautiful ecology. Specifically, it includes 4 first-level indicators and 35 second-level indicators, of which 31 second-level indicators are positive indicators and 4 are negative indicators. The evaluation of regional coordinated development level is calculated based on the data of Foshan city and the five districts from 2013 to 2022 (see **Table 1** for the specific index system).

Table 1. Comprehensive evaluation index system and weights for Foshan City.

Goal Level	System Level	Indicator Level	Attribute	Weight
Regional economies	Industrial Development (34.50%)	Regional Gross Domestic Product (GDP) (Unit: 100 million yuan)	+	2.412%
		Per Capita Regional GDP (Unit: 10,000 yuan/person)	+	1.913%
		General Public Budget Revenue (Unit: 100 million yuan)	+	3.294%
		Total Retail Sales of Consumer Goods	+	3.146%
		Tax Revenue as a Proportion of General Public Budget Revenue (Unit: %)	+	2.762%
		Per Capita Disposable Income of Residents (Unit: yuan/person)	+	1.592%
		Fixed Asset Investment (Unit: 100 million yuan)	+	1.849%
		Proportion of Added Value of Secondary Industry to Regional GDP (Unit: %)	+	0.640%
		Added Value of Industrial Enterprises above Designated Size (Unit: 100 million yuan)	+	2.485%
		Total Import and Export (Unit: 100 million yuan)	+	5.245%
		Urbanization Rate of Permanent Residents (Unit: %)	+	1.649%
	Infrastructure (32.32%)	Proportion of Infrastructure Investment to Fixed Asset Investment (Unit: %)	+	3.499%
		Total Length of Highways (Unit: kilometres)	+	3.289%
		Number of Bus Routes or Total Length of Bus Routes (Unit: kilometres)	+	2.231%
		Passenger Volume (Unit: 10,000 person-times)	+	10.854%
		Total Postal and Telecommunications Business (Unit: 100 million yuan)	+	6.300%
		Number of Fixed Internet Broadband Access Users (Unit: 10,000 households)	+	4.499%
		Number of Mobile Internet Broadband Access Users (Unit: 10,000 households)	+	3.662%
		Total Electricity Consumption of the Whole Society (Unit: 100 million kilowatt-hours)	+	3.383%
		Total Public Water Supply (Unit: 100 million cubic meters)	+	4.019%
	Public Services (21.84%)	Per Capita Expenditure on Basic Public Services for Permanent Residents (Unit: yuan/person)	+	3.215%
		Number of Health Technicians per 10,000 People	+	2.982%
		Proportion of Education Expenditure to GDP (Unit: %)	+	2.744%
		Coverage Rate of Pension Insurance (Unit: %)	+	1.294%
		Coverage Rate of Unemployment Insurance (Unit: %)	+	1.310%
		Number of Primary Medical and Health Institutions (Unit: units)	+	3.744%
		Collection of Books in Public Libraries (Unit: 10,000 volumes)	+	3.429%
		Number of Cultural Stations (or Cultural Centres) (Unit: units)	+	6.502%
Ecological condition	Ecological management (11.33%)	Proportion of Days with Good Air Quality (Unit: %)	+	0.917%
		Proportion of Surface Water Meeting or Exceeding Class III Water Quality (Unit: %)	+	0.983%
		Greening Coverage Rate (Unit: %)	+	0.379%
		Nitrogen Dioxide Concentration (Unit: micrograms/cubic meter)	–	0.894%
		Acid Rain Frequency (Unit: %)	–	0.901%
		Inhalable Particulate Matter PM10 (Unit: milligrams/cubic meter)	–	1.236%
		Fine Particulate Matter PM2.5 (Unit: milligrams/cubic meter)	–	0.745%

Firstly, the data is standardized, and then the entropy method is used to determine the weights of each indicator layer.

$$U_i = \sum_{j=1}^{k} x_{ij} w_{ij} \quad \sum_{j=1}^{n} w_{ij} = 1, \ \ i = 1,2,3,4 \quad (1)$$

Where:

- W_{ij} is denoted the weight of each indicator,
- U_i is the comprehensive evaluation score of each system,
- x_{ij} is the standardized value of each indicator.

The results of the weight calculation for each indicator are shown in **Table 1**.

3.2.2. Coupling Coordination Degree Model

In order to clarify the cooperativity among various systems, this paper introduces the concept of interadaptive collaboration in the synergy theory to measure the symbiotic relationship of each system layer in the target layer. The calculation method model is as follows:

$$C = 4\frac{\sqrt[4]{U_1 \times U_2 \times U_3 \times U_4}}{U_1+U_2+U_3+U_4} \quad D = \sqrt{C \times \mathrm{T}} \quad \mathrm{T} = \alpha U_1 + \beta U_2 + \gamma U_3 + \delta U_4 \tag{2}$$

The coupling degree of the system layer is denoted as *C*, with a value range between 0 and 1. $U_1, U_2, U_3\ and\ U_4$ represent the comprehensive evaluation scores of industrial development, infrastructure, public services, and green and beautiful ecology, respectively. *D* is the coupling coordination degree of the composite system of the five districts in industrial city, where a value closer to 1 indicates a higher coupling coordination degree. *T* is the comprehensive evaluation index of "industrial development-infrastructure-public services-green and beautiful ecology." The coefficients $\alpha, \beta, \gamma\ and\ \delta$ are the undetermined coefficients for industrial development, infrastructure, public services, and green and beautiful ecology, respectively, with $\alpha + \beta + \gamma + \delta = 1$. According to Weng et al. (2022), this study considers the four aspects equally important, so $\alpha, \beta, \gamma\ and\ \delta$ are all set to 0.25[36]. This study draws on existing research results to classify the coupling coordination degree levels, as detailed in **Table 2**.

3.2.3. Spatial Autocorrelation Analyses

To study the spatiotemporal distribution of high quality development, the global Moran's Index is used to describe the spatial aggregation characteristics and distribution patterns of the entire study area. The calculation formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(D_i - \bar{D})(D_j - \bar{D})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{3}$$

The local Moran's Index is as follows:

$$I_i = \frac{(D_i - \bar{D})}{S^2} \sum_{i \neq j}^{n} W_{ij}(D_j - \bar{D}) \tag{4}$$

Where:

- W_{ij} represents the spatial weight relationship,
- $\bar{D}$ is the average coupling degree,
- S^2 represents the variance,
- D_i and D_j represent the coupling degree indices of provinces in geographical space.

The value range of the Moran's Index is [–1, 1].

3.2.4. Relative Development Mode

This paper introduces the relative development model to evaluate the relative development situation between the indicators of the coordinated development of economy and ecological environment more intuitively,calculated by the formula:

$$E = U_1/U_2 \tag{5}$$

Where:

- E represents the relative degree of development of the two systems,

When E is less than 0.8, the U_1 system lags behind the development of the U_2 system; when 0.8 < E < 1.2, the U_1 and U_2 systems develop together; and when E is greater than 1.2, the U_1 system leads the development of the U_2 system. For E > 1.2, the U_1 system is ahead of the U_2 system, and so on for multi-system comparisons.

3.3. Data Sources for Indicators

This study utilizes data from various regions of Foshan City, sourced from the annual publications of the Foshan Statistical Yearbook, China City Statistical Yearbook, China Energy Statistical Yearbook, as well as the statistical yearbooks, statistical bulletins, and the China Marketization Index Database of Foshan's regions. For missing data on certain indicators, the interpolation method was used to complete the dataset.

Table 2. Classification of coupling coordination degree.

Coordination Level		Coordination Level	
$0 \leq D < 0.1$	Coordination level	$0.5 \leq D < 0.6$	Barely coordinated
$0.1 \leq D < 0.2$	Seriously unbalanced	$0.6 \leq D < 0.7$	Basic coordination
$0.2 \leq D < 0.3$	Moderately unbalanced	$0.7 \leq D < 0.8$	Intermediate coordination
$0.3 \leq D < 0.4$	Slightly unbalanced	$0.8 \leq D < 0.9$	Good coordination
$0.4 \leq D < 0.5$	On the verge of imbalance	$0.9 \leq D < 1$	High-quality coordination

4. Analysis of the Coordinated Development of Economy and Ecological Environment

4.1. Analysis of the Coordinated Development Level of Economy and Ecological Environment

The economic and ecological environment became more resilient and the level of coordination continued to improve.

From 2013 to 2022, the overall score of the coordinated development level of economy and ecological environment showed a strong upward trend (see **Figure 1**), increasing steadily from 13.5 points in 2013 to 78.2 points in 2022. This trend reflects the robust resilience and continuously improving coordination level in the economic and ecological environment in regional development. Despite the severe impacts of the COVID-19 pandemic and international trade challenges, the growth rate has maintained a stable upward trajectory. This indicates that the province has achieved significant progress in economic, social, and environmental development, with various regional indicators gradually improving and enhancing. This sustained growth trend also reflects the effective policies and practical measures taken by the government to promote the coordinated development of the economy and the ecological environment.

First, the pace of industrial upgrading, transformation, and innovation has accelerated, and the economic density has steadily increased. From 2013 to 2022, the industrial development dimension of the coordinated development level of economy and ecological environment exhibited an overall upward trend, with the score rising from 7.94 in 2013 to 25.33 in 2022 (see **Figure 1**). Although there was a decline in 2018, this may be attributed to the province's policy adjustments that year, specifically the comprehensive rectification of village-level industrial parks. During the rectification process, industrial development experienced some stagnation, but in 2019, the comprehensive score for industrial development saw a significant rise, indicating that the rectification efforts in 2018 were highly effective. This trend reflects Foshan's proactive exploration and improvements in industrial development, particularly in terms of upgrading industrial innovation and steadily increasing economic density. This progress is largely due to the increase in investment in industrial innovation and steady improvements in economic density.

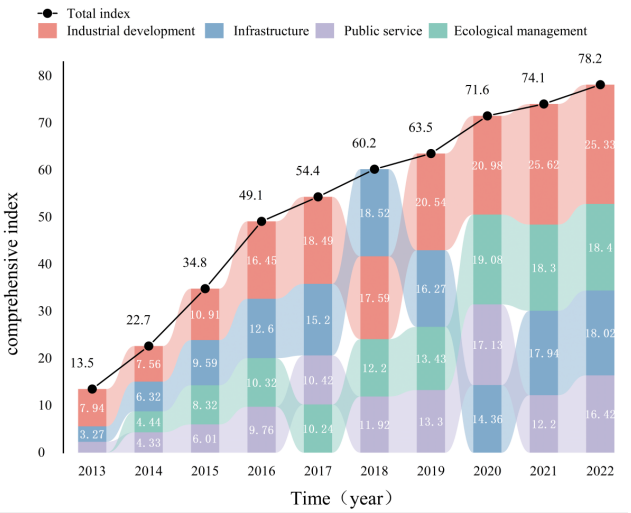

Figure 1. Comprehensive evaluation score of the coordinated development of economy and ecological environment.

Second, foundational support continues to be strengthened, with accelerated strides in digitalization. The infrastructure dimension of the coordinated development level of economy and ecological environment fluctuated between 2019 and 2021, likely due to the severe impacts of the COVID-19 pandemic. However, by 2022, infrastructure had returned to pre-pandemic levels, indicating concerted efforts in post-pandemic infrastructure development. This trend reflects the city's ongoing consolidation and improvement of infrastructure, especially in the strengthening of foundational support and the continuous enhancement of

information transmission efficiency. Public services have improved steadily, and people's well-being has continued to be strengthened. The public service dimension of regional economy and ecological environment developing in harmony displayed a stable upward trend from 2013 to 2022 (see **Figure 1**), with the score rising from 2.3 in 2013 to 16.42 in 2022. However, due to the impact of the COVID-19 pandemic, there were significant fluctuations in public services from 2019 to 2021. This suggests that China needs to take a more comprehensive approach to ensure people's livelihood and security.

Finally, in terms of green ecology, the environmental situation of this industrial city is still challenging, but the overall trend is stable and improved. The ecological management dimension of the coordinated development level of economy and ecological environment saw its score soar to 18.4 in 2022, ranking second among the four dimensions and showing substantial improvement. This data shows that some achievements have been made in ecological environment protection and improvement in the past decade, and also reflects the government's attention to the ecological environment and the continuous promotion of greening work under the background of the gradual development of the greening trend. The data shows a significant upward trend in the ecological management dimension over the past ten years. This reflects the importance the government attaches to ecological improvement work, resulting in remarkable achievements. However, as urbanization accelerates, industrial development progresses, and the costs of pollution control rise, maintaining ecological stability poses ongoing challenges.

According to the change trend of the comprehensive evaluation scores of each district (see **Figure 2**), the overall ranking has remained relatively stable, from highest to lowest: Shunde District, Nanhai District, Chancheng District, Gaoming District, and Sanshui District. It is evident that Shunde, Nanhai, and Chancheng continue to be the core areas driving Foshan's development, maintaining an upstream level with a notable advantage over Gaoming and Sanshui. Over time, the overall level of coordinated development across Foshan's districts has also shown consistent and steady growth.

4.2. Analysis of the Coupling Coordination Degree

The coupling coordination degree of the composite system in five districts from 2013 to 2022 was calculated using the coupling coordination degree model. **Table 3** shows the coupling coordination degree of the composite system in Foshan's five districts and their corresponding coordination levels.

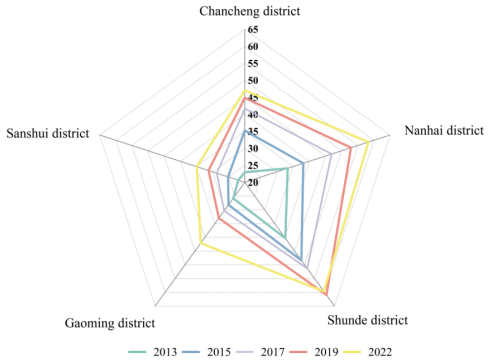

Figure 2. The score of the comprehensive evaluation of the coordinated development level of regional economy and ecological environment in Foshan.

From the temporal changes in the coupling coordination degree across districts, it is evident that the overall trend is one of steady progress.

Shunde District, benefiting from its strategic position within the Guangdong-Hong Kong-Macao Greater Bay Area and the well-developed infrastructure supporting its industrial clusters, has consistently maintained a leading position in Foshan. By 2014, it had reached the basic coordination level, achieved intermediate coordination in 2017, and its composite system continued to maintain good coordination development by 2022. Nanhai District has consistently maintained an upstream level of coordinated development. Before 2015, it was at the barely coordinated level, progressed to basic coordination from 2015 to 2018, and has sustained intermediate coordination since 2018. Chancheng District, with limited land and space, has adopted a clear development strategy focused on improving development quality within the available space. As a result, it also advanced from basic to intermediate coordination in 2022. Gaoming and Sanshui Districts have strengths in ecological construction, and their coupling coordination degrees have been consistently increasing, with growing momentum in coordination. However, during the past decade, these two districts have remained at the barely coordinated level. Since 2013, all five districts have reached a level of coordinated development. By 2016, three districts had achieved the basic coordination level, representing 60% of the total, and by 2022, these three districts had all progressed to intermediate coordination.

Table 3. Coupling Coordination Degree of Foshan's Composite System from 2013 to 2022.

Year	San Shui		Gao Ming		Shun De		Nan Hai		Chan Cheng	
2013	Barely Coordinated	0.41	Barely Coordinated	0.46	Barely Coordinated	0.60	Barely Coordinated	0.54	Barely Coordinated	0.52
2014	Barely Coordinated	0.41	Barely Coordinated	0.46	Primary Coordination	0.61	Barely Coordinated	0.54	Barely Coordinated	0.58
2015	Barely Coordinated	0.43	Barely Coordinated	0.45	Primary Coordination	0.69	Primary Coordination	0.60	Primary Coordination	0.63
2016	Barely Coordinated	0.44	Barely Coordinated	0.48	Primary Coordination	0.69	Primary Coordination	0.64	Primary Coordination	0.65
2017	Barely Coordinated	0.48	Barely Coordinated	0.48	Intermediate Coordination	0.71	Primary Coordination	0.67	Primary Coordination	0.67
2018	Barely Coordinated	0.48	Barely Coordinated	0.50	Intermediate Coordination	0.74	Primary Coordination	0.69	Primary Coordination	0.69
2019	Barely Coordinated	0.49	Barely Coordinated	0.51	Intermediate Coordination	0.77	Intermediate Coordination	0.71	Primary Coordination	0.70
2020	Barely Coordinated	0.50	Barely Coordinated	0.54	Intermediate Coordination	0.74	Intermediate Coordination	0.74	Primary Coordination	0.68
2021	Barely Coordinated	0.50	Barely Coordinated	0.54	Intermediate Coordination	0.73	Intermediate Coordination	0.74	Primary Coordination	0.70
2022	Barely Coordinated	0.50	Barely Coordinated	0.56	Intermediate Coordination	0.74	Intermediate Coordination	0.75	Intermediate Coordination	0.70
Mean Value	Barely Coordinated	0.46	Barely Coordinated	0.50	Intermediate Coordination	0.70	Primary Coordination	0.66	Primary Coordination	0.65
Rank	5		4		1		2		3	

From the analysis, it is evident that during the study period, there are significant differences in the coupling coordination levels of the composite systems across the districts. While all districts have reached a coordination level, the coordination quality in Sanshui and Gaoming Districts remains low, indicating a significant imbalance in regional development. In terms of spatial evolution trends of the coupling coordination degree, there are notable differences in spatial distribution, displaying a stable spatial pattern of "high in the east, moderate in the centre, and low in the west."

Combining the temporal changes and spatial evolution trends in the coupling coordination degree, it can be concluded that overall, the coupling and coordination degree of this industrial big city is showing a positive development trend. This progress can be attributed to a series of measures implemented by the municipal Party committee and the municipal government, such as the strategic goal of high-quality development proposed by the government, emphasizing the need for coordinated development to achieve rapid, high-quality progress.

4.3. Spatiotemporal Distribution Characteristics of the Coupling Coordination Degree of High-Quality Development

This study employs adjacent distance spatial weights to conduct a spatial autocorrelation analysis of the coupling degree of high-quality development across various districts in Foshan from 2013 to 2022.

4.3.1. Global Spatial Autocorrelation Analysis

Based on Equation (3), the global Moran's I index for the coupling degree of high-quality development from 2013 to 2022 was calculated, as shown in **Table 4**.

The relevant indicators are all positively correlated and have passed the significance test, indicating that the spatial distribution of the coupling degree of high-quality development in each region of China is not random. It exhibits spatial autocorrelation, clustering, and a positive distribution. From a time series perspective, the global Moran's I index of the provinces along the line from 2013 to 2022 shows a fluctuating upward trend, with three increases in 2014, 2021, and 2020, and reaching the peak of the research stage in 2017. This indicates that under the condition of spatial positive correlation, the spatial clustering trend of the coupling degree of high-quality development in various districts fluctuates greatly, influenced by factors such as environmental protection policies, income disparity, industrial distribution, and unexpected public events. There are both rises and falls. It also indicates that the overall high-quality development stage of various districts is not yet achieved, being greatly affected by external factors and having weak self-risk resistance.

4.3.2. Local Spatial Autocorrelation Analysis

To further investigate the spatial clustering characteristics of the provinces along the line, based on Equation (4), the local spatial autocorrelation coefficients within the regions of the provinces along the line were measured using the adjacent distance spatial weight matrix. Drawing on previous research (Wang, 2024), the local Moran's I index of regional high-quality development coupling was divided into four quadrants. The years 2013, 2016, 2019, and 2022 were selected as observation years, and the local spatial autocorrelation of the coupling degree of high-quality development in Foshan is shown in **Table 5**.

From the characteristics of the clustering distribution, Chancheng District, Nanhai District, and Shunde District mainly appear in the high-high level clustering area for many years, while Sanshui District and Gaoming District generally appear in the low-low level clustering area. In 2022, Nanhai District dropped to the high-low level clustering area, possibly due to the industrial structure adjustment in Nanhai District after the COVID-19 pandemic or the contraction of domestic and international demand. At the same time, Nanhai District has also been under significant environmental pressure. In the same year, Sanshui District also rose to the high-low development area, with the momentum of coordination continuously strengthening.

Comparing the four different time points of 2013, 2016, 2019, and 2021, it can be clearly seen that the provinces located in the high-level clustering area and the development transition area rarely undergo transitions. There have been changes between the low-level clustering area and the radiation-driven area, but the fluctuations are not significant. This shows that each district has not yet entered the stage of high-quality development, and is in urgent need of transformation and upgrading.

Table 4. Global Moran's I Index of Foshan.

Year	Moran's I	Year	Moran's I
2013	0.294**	2018	0.487**
2014	0.464***	2019	0.475***
2015	0.496***	2020	0.349***
2016	0.491**	2021	0.379**
2017	0.515***	2022	0.333*

Note: ***, **, and *, respectively, represent passing the significance test at the level of 1%, 5%, and 10%.

Table 5. Local spatial clustering of various districts in Foshan.

Year	H-H	H-L	L-H	L-L
2013	Chancheng, Nanhai, Shunde			Sanshui, Gaoming
2016	Chancheng, Nanhai, Shunde			Sanshui, Gaoming
2019	Chancheng, Nanhai, Shunde			Sanshui, Gaoming
2022	Chancheng, Shunde	Nanhai	Sanshui	Gaoming

4.4. Analysis of Relative Levels of Development

From Equation (5), we can calculate the relative development degree E1, E2, E3, E4 between industrial development, infrastructure, public service, and economical management, and determine the specific development type according to the rules of value. When E1 is the smallest value in the ratio of four groups, it is defined as industrial development lag type; when E2 is the smallest value in the ratio of four groups, it is defined as infrastructure lag type; when E3 is the smallest value in the ratio of four groups, it is defined as public service lag type; when E4 is the smallest value in the ratio of four groups, it is defined as eco-management lag type; when E1, E2, E3 and E4 are in the range of (0.8,1.2), it is defined as synchronous development type. As shown in **Table 6**.

From the comprehensive degree taken from 2013–2022, among the five districts of Foshan City, only Shunde District is a Synchronous development type, with balanced development of industry, infrastructure, public services and ecological management; Chancheng District and Gaoming District both belong to the infrastructure lag type, in which the ecological management of Chancheng District and Gaoming District is more outstanding; Nanhai District and Sanshui District are the infrastructure lag type, in which Sanshui District is more outstanding for the other three areas of development, ecological management is also more outstanding. From the above analysis, it can be seen that the ecological management performance of various regions is relatively good, indicating that the Chinese government's efforts in coordinating the regional ecological development have achieved significant results.

From the time period, Chancheng District in 2014 was the synchronous development type, but after that has been developed for the public service lag type; after 2019, due to the Corona Virus Disease 2019, Chancheng District developed for the infrastructure lag type; at the same time suffered from the impact of the new crown epidemic and the Shunde District. Before the year of 2020, Shunde District was basically synchronous development type, but after the epidemic has become a public service lag type; the Nanhai District being basically always for public services lagging type, this may be due to the area of the Nanhai District is relatively large compared to other regions, part of the suburbs of the infrastructure improvement will face greater pressure. Gaoming District is always lagging in infrastructure, while Sanshui District is always lagging in public services.

To sum up, the lag of infrastructure and public service has become the main reasons affecting the coordinated development of urban areas. Therefore, while vigorously developing the economy, attention should be paid to improving the level of infrastructure and public service.

5. Conclusions and Suggestions

5.1. Conclusions

This paper systematically reviews the concept of regional coordinated development and based on the entropy method, coupling coordination degree model, and spatial

Table 6. Relative development degree.

Year	Chancheng	Nanhai	Shunde	Gaoming	Sanshui
2013	Ecological management lag type	Ecological management lag type	Ecological management lag type	Infrastructure lag type	Public services lag type
2014	Synchronous development type	Public services lag type	Ecological management lag type	Infrastructure lag type	Public services lag type
2015	Public services lag type	Public services lag type	Ecological management lag type	Infrastructure lag type	Public services lag type
2016	Public services lag type	Public services lag type	Synchronous development type	Infrastructure lag type	Public services lag type
2017	Public services lag type	Public services lag type	Synchronous development type	Infrastructure lag type	Public services lag type
2018	Public services lag type	Public services lag type	Synchronous development type	Infrastructure lag type	Public services lag type
2019	Public services lag type	Public services lag type	Synchronous development type	Infrastructure lag type	Public services lag type
2020	Infrastructure lag type	Public services lag type	Public services lag type	Infrastructure lag type	Public services lag type
2021	Infrastructure lag type	Public services lag type	Public services lag type	Infrastructure lag type	Public services lag type
2022	Infrastructure lag type	Public services lag type	Public services lag type	Infrastructure lag type	Public services lag type
Comprehensive degree	Infrastructure lag type	Public services lag type	Synchronous development type	Infrastructure lag type	Public services lag type

econometric model, establishes a comprehensive evaluation index system for regional coordinated development levels that includes four primary indicators and 35 secondary indicators. It collects panel data from 2013–2022 to measure the regional coordinated development level, coupling coordination degree, and spatial Moran's index for each region across different years. Finally, the paper analyzes the regional economy and ecological environment coordinated development level of time trend and spatial distribution:

- The overall coordinated development trend is favourable. The coordinated development level of regional economy and ecological environment is rising, with the development gap between regions gradually narrowing but still present. The coordinated development level of regional economy and ecological environment exhibits a gradient decline from east to central to north.
- The temporal trend is positive, and the spatial pattern is stable. Currently, all districts have generally reached a level of coupling coordination. From the perspective of temporal changes in the coupling coordination degree across districts, the composite systems of the districts have consistently maintained a good development trend. In terms of spatial evolution trends, there are significant differences in the spatial distribution of the coupling coordination degree of the composite systems across regions, showing a stable spatial evolution pattern of "higher in the east, moderate in the centre, and lower in the west."

The spatial clustering trend of high-quality development city is highly volatile, and regional disparities are quite apparent. Therefore, China is not yet in a stage of high-quality coordinated development and is significantly affected by external factors, necessitating transformation and upgrading. The lag of infrastructure and public service will affect the coordinated development of the regional economy in each district. It is worth noting that the overall data in terms of ecological environment show a stable and good trend.

5.2. Suggestions

- Implement stringent ecological and environmental protection measures. Under the background of high-quality development of the town economy, the primary task of promoting the coordinated development of economy and ecology is to implement strict ecological environment protection measures. For the eastern regions with a high level of economic development but great ecological environment pressure, we should focus on promoting green transformation, strengthening ecological environment management and improving resource utilization efficiency; for the central and western regions with relatively backward economic development but good ecological environment, we should encourage developing green industries such as ecological agriculture and eco-tourism, and strengthen infrastructure construction and improve the public service level, so as to lay a solid foundation for economic development. At the same time, the government should formulate and implement strict environmental laws and regulations, strictly regulate pollution discharge, resource utilization and other behaviors, and ensure that economic activities are carried out within the carrying capacity of the ecological environment. In addition, we should strengthen the protection of areas sensitive to the ecological environment and key ecological function areas, restrict or prohibit economic activities that cause irreversible damage to the ecological environment, protect biodiversity and maintain ecological balance.
- Promote green production methods and build a green consumption system. Promoting green pro-

duction mode is an important way to realize the coordinated development of economy and ecology. The government should encourage enterprises to adopt clean energy, energy-saving technologies and environmentally-friendly equipment to reduce energy consumption and pollution emissions in the production process. At the same time, strengthen the research and development and promotion of green production technology, improve the efficiency of resource utilization, reduce waste production, and realize circular and green economic activities. Through the promotion of green production mode, the industrial structure will be transformed to high-end, intelligent and green, and the coupling and coordination degree will be improved. This can not only improve the economic benefits of enterprises, but also reduce the negative impact on the ecological environment, strengthen the transformation and upgrading of traditional industries, and improve their environmental performance and market competitiveness. At the same time, consumers should also be guided to establish the concept of green consumption, encourage the purchase of environmentally friendly products, the use of renewable energy, and reduce the use of disposable goods. We will strengthen supervision over the green consumer market, crack down on illegal activities such as false publicity, counterfeiting and shoddy products, and protect the legitimate rights and interests of consumers. The construction of a green consumption system can promote the formation of green, low-carbon and circular consumption patterns, and promote the coordinated development of economy and ecological environment.

- Strengthen city-level coordination, reduce fragmentation, and enhance integration. To achieve synergistic development, China must bolster urban-level coordination, facilitate inter-regional resource sharing, foster unity, and minimize fragmentation in public transportation, public services, and industrial layouts. Provincial authorities should expedite cross-regional road network construction, prioritize transportation projects, enhance transportation hub connectivity, and vigorously promote cross-regional subway projects. In public services, especially education and healthcare, regions must align standards and reduce disparities. This involves deepening cross-regional school cooperation, promoting collectivized school operations, facilitating teacher exchanges, and establishing joint lesson preparation and examination mechanisms. In healthcare, high-quality medical resources should be extended to less developed regions through hospital co-construction projects and training for pharmacists, family pharmacy leaders, and educators. Government services should also be cross-regionally accessible to provide convenient public services. Provinces should leverage regional advantages to advance industrial spatial layouts, strengthening district-town coordinated development and driving rural progress. Regions must deepen integration, consolidate collaboration mechanisms, leverage leading regions' spillover effects, and tap into less developed regions' potential.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by X.T., X.R. and D.L. The first draft of the manuscript was written by X.T. and R.L. adjusted the format of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability Statement

The data that support the findings of this study are available from Foshan Bureau of Statistics, but restrictions apply to the availability of these data, which were used under licence for the current study and so are not publicly available. The data are, however, available from the authors upon reasonable request and with the permission of Foshan Bureau of Statistics.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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