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Spatio-temporal Coupling Analysis of Population Urbanization and Economic Development in Yangtze River Delta Urban Agglomeration

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Abstract: Population urbanization and economic development are highly correlated, and the degree of coordination between the two has gradually become one of the important issues for the healthy development of the region. With the advancement of high-quality integration in the Yangtze River Delta, it is particularly important to clarify the coupling and coordination process and spatial differentiation between population urbanization and economic development for the future integration and sustainable development of the Yangtze River Delta region. Given this, we establish a comprehensive evaluation index system of population urbanization and economic development based on the period of 2009–2020. Taking the Yangtze River Delta urban agglomeration as the research object, the entropy method and the coupling coordination model are used to carry out Spatio-temporal coupling analysis. The results show that (1) the level of population urbanization and economic development of the Yangtze River Delta urban agglomeration is continuously rising, while economic development lags behind population urbanization development, and the economic development level needs to be further improved. The degree of coupling coordination of population urbanization and economic development has continued to increase, and the synergistic development effect of the two has been improved, (2) the comprehensive level of population urbanization and economic development of each city in the Yangtze River Delta urban agglomeration shows an obvious inter-regional unbalanced development trend, and (3) there is an obvious polarization in the coupling coordination level between population urbanization and economic development in the Yangtze River Delta urban agglomeration.

Keywords: Yangtze River Delta Urban Agglomeration; Population Urbanization; Economic Development; Entropy Method; Coupling Coordination

1. Introduction

With the largest population, China's economy has been advancing, and the level of urbanization has steadily improved since the reform and opening up more than 40 years ago. The speed and scale of urbanization in China are among the top in the world. In terms of scale and speed, by the end of 2021, the national urban resident population reached 9.1425 million, and the urbanization rate was 64.72%, which increased by 1.25 million or 0.83% compared with the end of 2020. From 10.64% at the beginning of the founding of New China to 64.72% today, China has completed the perfect transformation from "rural China" to "urban China". Cities play an important role in people's production, life, and consumption as an important engine of modernization. As a necessary way for a country's economic and social development, understanding its meaning, characteristics, and development trend are of great significance to the modernization of the country. Researchers have different definitions of urbanization due to differences in academic background. Urbanization is a multi-dimensional concept, including economic, demographic, and social and spatial dimensions. Among them, population urbanization is important, economic growth is the driving force, and urbanization is the product of social and economic development to a certain extent. China's s urbanization is in a stage of rapid development. Only by properly handling the relationship between population urbanization and economic development, economic transformation and upgrading, and new urbanization are carried out quickly and effectively.

In order to correctly understand the interaction between population urbanization and economic development, Bailey proved by principal component analysis that there is an obvious positive correlation between them [1]. Chenery proposed a certain positive correlation between the two through empirical research [2]. In China, many scholars have also explored the relationship between the two. Gu [3] argued that urbanization and economic development promote each other through empirical analysis of urbanization in Zhejiang and Jiangsu and that China's urbanization process is advancing. Zhao verified the "urbanization effect" in the process of economic development based on time series data analysis [4]. Zhu, Li, and Le used the unit root test and data cointegration test

of panel data to conclude that there is a long-term stable equilibrium relationship between the urbanization process and economic development level [5]. Chen proposed that there is a complex two-way feedback effect between urbanization and economic development [6]. Zhou, Che, and Sun used entropy weight-catastrophe progression, coupling coordination model, and spatial autocorrelation model to show that there is a significant correlation between urbanization and economic growth, and economic growth has a significant positive role in promoting urbanization [7].

From the literature review, a close relationship is found between urbanization and economic development. There have been numerous studies on the relationship between population urbanization and economic development but most of them have been conducted at the national and provincial levels. After China entered the 21st century, few researchers systematically analyze the relationship between population urbanization and economic development based on the level of urban agglomerations. Although the Yangtze River Delta urban agglomeration is the core region of quality development in China with the total economic volume and urbanization rate consistently ranking among the top urban agglomerations, the situation within the region is complex, and the development differences between cities still exist. This reflects the current situation of unbalanced development in China. The unbalanced development of the Yangtze River Delta urban agglomeration is caused by many factors, including historical factors, geographical location, resource allocation, population structure, and ideology. Therefore, it is particularly important to find a method to promote healthy and orderly urbanization and healthy economic development and promote the sustainable development of the whole region. In view of this, we select the Yangtze River Delta urban agglomeration, a typical representative of China's urban agglomerations as the research area and establish a corresponding comprehensive evaluation index system based on the relationship between population urbanization and economic development. Based on the entropy method and the coupling coordination degree model, the coupling coordination relationship between the two is studied from multiple dimensions, and the Spatio-temporal evolution law is explored. We attempt to put forward development countermeasures and suggestions for the actual problems of the Yangtze River Delta urban agglomeration through empirical research for promoting the development of cities in the Yangtze River Delta urban agglomeration and achieving regional high-quality integration.

2. Research Area, Method, and Index System

2.1 Overview of Research Area

The Yangtze River Delta urban agglomeration is located in the plain of the lower reaches of the Yangtze River in eastern China. It includes 26 cities in Shanghai, Jiangsu, Zhejiang, and Anhui provinces with an area of 211.7 million km^2 and a total population of over 225 million. In 2020, the total GDP of the Yangtze River Delta urban agglomeration was 20510.6 billion yuan, and the urbanization rate was 75.01%. The overall level of urbanization has reached a high level, which is 11.12% higher than the national average.   It is the region with the highest and most dynamic level of economic development, the strongest comprehensive strength and the greatest influence in China, and has an important strategic position in the overall situation of China's modernization, and is the leader of the new urbanization construction.

2.2 Research Methods

2.2.1 Entropy Method

The entropy method is an objective weighting method to determine the discrete degree of an index. To avoid the deviation caused by arbitrary factors and the arbitrariness of index weight determination and ensure the accuracy of the calculation of population urbanization and economic development level of prefecture-level cities in the Yangtze River Delta urban agglomeration, we use the improved entropy method evaluation model to comprehensively evaluate the population urbanization and economic development system of the Yangtze River Delta urban agglomeration [8]. The main steps are as follows.

(1) Index selection: if there are m years, r cities, and n indexes, X_{yij} is the jth index value of city i in the yth year.

(2) Standardization of indicators: Standardization of positive indexes: $Z_{yij} = (X_{yij} - X_{min})/(X_{max} - X_{min})$, standardization of negative indexes: $Z_{yij} = (X_{max} - X_{yij})/(X_{max} - X_{min})$

In the equation, X_{max} and X_{min} represent the maximum and minimum values of the jth index respectively; X_{yij} and Z_{yij} represent the values of the jth index before and after standardization respectively.

(3) Index normalization: $P_{yij} = Z_{yij}/\sum_m \sum_r Z_{yij}$

(4) Calculate the entropy of each index: $E_j = -k \sum_m \sum_r P_{yij} \ln P_{yij}$, and $k = 1/\ln(m \times r)$

(5) Calculate the redundancy of each index: $D_j = 1 - E_j$

(6) Calculate the weight of each index: $W_j = D_j / \sum_j D_j$

(7) The comprehensive evaluation index is obtained by the linear weighting method: $U_{yi} = \sum_j (W_j \times Z_{yij})$

2.2.2 Coupling Coordination Model

"Coupling" refers to the phenomenon that two or more systems affect each other through interaction. Based on the concept of coupling in physics and relevant research results [9], the research constructs a theoretical model of coupling coordination with the following calculation.

$$C = \{U \times V / [(U + V)/2]^2\}^K \tag{1}$$

$$T = \alpha U + \beta v \tag{2}$$

$$D = \sqrt{C \times T} \tag{3}$$

where U is the comprehensive evaluation index of population urbanization, V is the comprehensive evaluation index of economic development, C is the coupling degree, D is the coupling coordination degree, K=2 is the adjustment coefficient, T is the comprehensive evaluation index of population urbanization and economic development, and α and β are undetermined coefficients. Since the two systems of population urbanization and economic development are equally important, both are taken as 0.5. In this study, the coupling coordination degree is divided according to the previous research results and the actual characteristics of the Yangtze River Delta urban agglomeration, as shown in Table 1.

Table 1. Classification of Coupling Coordination Degree

Interval	Coupling level	Coordination level
0＜C≤0.3	Low coupling	Low coupling coordination
0.3＜C≤0.5	Antagonistic phase	Moderate coupling coordination
0.5＜C≤0.8	Run-in stage	High coupling coordination
0.8＜C≤1	High coupling	Extreme coupling coordination

2.3 Index System Construction and Data Sources

2.3.1 Construction of Index System

In order to comprehensively and objectively evaluate the coupling coordination development relationship between population urbanization and economic development in the Yangtze River Delta urban agglomeration, we establish a scientific and reasonable evaluation index system (Table 2) based on the existing literature [10,11], combined with the systematicness, representativeness, comparability of indexes and availability of data.

Table 2. Comprehensive evaluation index system of population urbanization and economic development

Level I Indexes	Level II Indexes	Level III Indexes	Effectiveness of Indexes	Weight
Population Urbanization	Population size (0.608)	Urban population (thousands)	+	0.3389
		Population density (person/km2)	+	0.2691
	Population structure (0.1302)	Proportion of urban population (%)	+	0.0649
		Proportion of employed persons in secondary and tertiary industries (%)	+	0.0653
	Living standard	Engel coefficient of urban residents (%)	-	0.0471

Economic development	(0.2618)	Per capita disposable income of urban residents (Yuan)	+	0.1321
		Urban registered unemployment rate (%)	-	0.0826
	Economy of scale (0.5639)	GDP (100 million yuan)	+	0.2125
		General public budget revenue (100 million yuan)	+	0.3514
	Economic level (0.1528)	GDP per capita (yuan)	+	0.0632
		General public budget revenue per capita (yuan)	+	0.0896
	Economic structure (0.2388)	Output value of secondary and tertiary industries (100 million yuan)	+	0.2219
		Proportion of output value of secondary and tertiary industries to GDP (%)	+	0.0169
	Economic speed (0.0445)	GDP growth rate (%)	+	0.0173
		General public budget revenue growth rate (%)	+	0.0272

The indexes in Table 2 are described as follows.

(1) Population size: The two evaluation indexes in this system directly reflect the number of urban population and the carrying capacity of cities to population.

(2) Population structure: Two indexes are used to measure the level of urbanization and employment structure respectively.

(3) Living standard: The Engel coefficient of urban residents, urban registered unemployment rate, and other three indexes are included. On the one hand, these three indexes measure the degree of universalization of modern urban lifestyles, and on the other hand, they reflect the connotation of new urbanization as"people-oriented"[12].

(4) Economic size: There are two indexes. GDP reflects the size of regional economic development, used to determine the overall strength of the economy, and the general public budget revenue directly reflects the financial resources available to the region.

(5) Economic level: The two evaluation indexes in this system measure the living standard of the people and objectively reflect the development level and degree of development of the region.

(6) Economic structure: The two evaluation indexes in this system reflect the value created by employees in the industrial service industry and the optimization of industrial structure. They measure the degree of labor force employment absorption by industrialization and reveal the impact of economic development on the level of population urbanization.

(7) Economic speed: GDP growth rate and general public budget revenue growth rate are included as dynamic indexes reflecting the changes in the overall economic situation of the region in different years.

2.3.2 Data Sources

A total of 26 cities in the Yangtze River Delta urban agglomeration including Shanghai, Nanjing, and Wuxi are selected as the sample for analysis, and the research period is the time series from 2009 to 2020. The original data are obtained from the statistical yearbooks of each province and the statistical bulletins of the national economic and social development of each city in the corresponding years.

3. Results and Analysis

3.1 Analysis of population urbanization and economic development based on time series

3.1.1 Analysis of comprehensive development level

The entropy method is used to calculate the weight value of each index (Table 2). According to the normalized value, the comprehensive evaluation indexes of population urbanization and economic development of the Yangtze River Delta urban agglomeration are calculated respectively. At the same time, to describe the changing trend of population urbanization and economic development index of the Yangtze River Delta urban agglomeration from 2009 to 2020 more intuitively, the trend charts of the two are drawn (Figure 1).
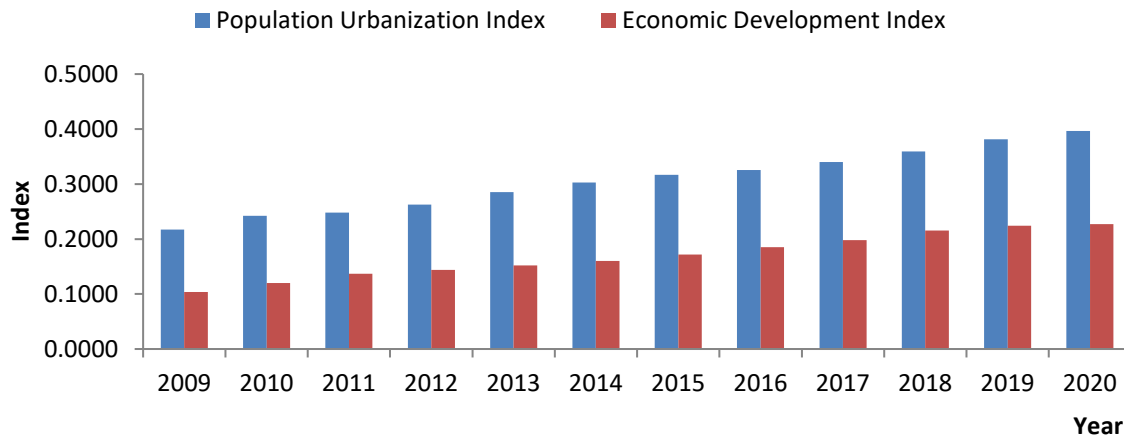

Figure 1. Trend chart of population urbanization and economic development index of Yangtze River Delta urban agglomeration from 2009 to 2020

The level of population urbanization has steadily improved. The urbanization process of the Yangtze River Delta urban agglomeration has been accelerating from 2009 to 2020. From the weight value of the evaluation index, the weight of the urban population is the largest, which is 0.3389, indicating that the scale of the urban population is the main factor affecting the level of population urbanization in the Yangtze River Delta urban agglomeration. The weights of population density and per capita disposable income of urban residents are also above 0.1300, indicating that these indexes also have a greater impact on the level of population urbanization. From the subsystem level, the weight value of the living standard is 0.2618, ranked third. The weight value of population size is the highest at 0.6080, indicating that the improvement of population urbanization level in the Yangtze River Delta urban agglomeration is mainly manifested in the expansion of scale and improvement of living standard. The larger the population urbanization index is, the higher the level of population urbanization is. As shown in Table 3, the population urbanization index increased from 0.2174 to 0.3964 from 2009 to 2020 year by year, indicating that the population urbanization level of the Yangtze River Delta urban agglomeration has steadily improved.

As the most developed economic core region in China, the Yangtze River Delta occupies an important role in the national economy, with the most active economic development. From the weight value of the evaluation index, the weight of the general public budget revenue is the largest, 0.3514, which is the most important factor affecting the economic development of the Yangtze River Delta urban agglomeration. The weight of the secondary and tertiary industry output value is 0.2219, which shows that the industry and service industry of the Yangtze River Delta urban agglomeration has developed rapidly. The weight of GDP, per capita general public budget revenue, and per capita GDP are also more than 0.063, indicating that these factors have a great impact on economic development. From the subsystem level, the weight value of the economic scale is 0.5639. The economic structure is 0.2388, ranked second, indicating that the improvement of the economic development level of the Yangtze River Delta urban agglomeration is mainly reflected in the expansion of economic scale and the optimization and upgrading of economic structure. The economic development index also reflects economic development to a certain extent. The economic development index increased from 0.1038 to 0.2271, which increased more than twice. Overall, the economic development of the Yangtze River Delta urban agglomeration showed a steady upward trend from 2009 to 2020.

3.1.2 Coupling Coordination Analysis

The coupling coordination degree is increasing year by year. The data in Table 3 and Figure 2 shows that the coupling degree of population urbanization and economic development in the Yangtze River Delta urban agglomeration from 2009 to 2020 shows a

fluctuating but upward trend as a whole. The coupling degree changes from the running-in stage to the high-level coupling stage, and the coordination degree shows an upward trend year by year. It gradually changes from moderate coupling coordination to high coupling coordination, indicating that the coupling coordination between population urbanization and economic development is increasing every year. From the comprehensive evaluation index of population urbanization and economic development (Table 3), the economic development index of the Yangtze River Delta urban agglomeration from 2009 to 2020 is significantly less than the population urbanization index, and the regional economic development lags behind the population urbanization. It is mainly due to the acceleration of economic transformation and upgrading of the Yangtze River Delta urban agglomeration from the pursuit of high GDP growth to realize the synchronous growth of residents' income and fiscal revenue and economy and focus on improving people's livelihood. This indicates that the Yangtze River Delta urban agglomeration is focusing on improving the quality of population urbanization development while maintaining stable economic development.
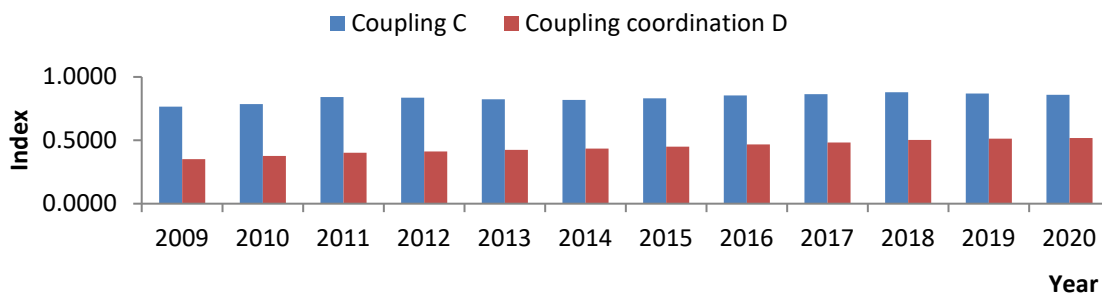

Figure 2. Evolution of coupling degree C and coordination degree D of population urbanization and economic development in the Yangtze River Delta urban agglomeration from 2009 to 2020

Table 3. Comprehensive evaluation index, coupling degree and coordination degree of population urbanization and economic development in the Yangtze River Delta urban agglomeration from 2009-2020

Year	Population Urbanization Index	Economic Development Index	Coupling C	Comprehensive index T	Coupling coordination D
2009	0.2174	0.1038	0.7653	0.1606	0.3506
2010	0.2421	0.1202	0.7866	0.1812	0.3775
2011	0.2481	0.1369	0.8401	0.1925	0.4022
2012	0.2625	0.1439	0.8371	0.2032	0.4124
2013	0.2851	0.1522	0.8238	0.2187	0.4244
2014	0.3027	0.1602	0.8194	0.2315	0.4355
2015	0.3166	0.1720	0.8325	0.2443	0.4510
2016	0.3256	0.1854	0.8551	0.2555	0.4674
2017	0.3402	0.1977	0.8646	0.2690	0.4822
2018	0.3591	0.2153	0.8785	0.2872	0.5023
2019	0.3813	0.2242	0.8699	0.3028	0.5132
2020	0.3964	0.2271	0.8580	0.3118	0.5172

3.2 Analysis of Population Urbanization and Economic Development Based on Spatial Sequence

3.2.1 Analysis of Spatial Differences in Comprehensive Development Levels

Overall, the spatial distribution of population urbanization level of 26 cities in the Yangtze River Delta urban agglomeration from 2009 to 2020 shows that coastal cities and provincial capital cities are relatively developed, while inland cities and marginal

areas are relatively backward in regional differentiation. As shown in Table 4, the average index of population urbanization in Shanghai is 0.8342, much higher than that of the other 25 cities, which fully reflects Shanghai's dominant position as the central city of the Yangtze River Delta urban agglomeration. The average index is between 0.5 and 0.3 in Suzhou, Nanjing and Wuxi, among which Nanjing, Hangzhou, and Hefei are provincial capitals, and Nantong, Ningbo, and Jiaxing are coastal cities. Jinhua, Taizhou, Maanshan, and other cities have an average index between 0.2 and 0.3. The rest below 0.2 are Chizhou, Anqing, Xuancheng, Chuzhou, and Tongling. These cities are inland and located in marginal areas. Due to the factors of history, location, and policies, the coastal cities, and provincial capitals have a larger urban population, higher quality, more reasonable employment structure, and higher living standard of people, which leads to a higher level of population urbanization in coastal cities than inland marginal areas and the higher level of population urbanization in provincial capitals than other prefecture-level cities. From 2009 to 2020, the average index of economic development of 26 cities in the Yangtze River Delta urban agglomeration is similar to that of population urbanization. The level of economic development is also obviously characterized by the developed coastal cities and provincial capital cities, while the inland cities and marginal areas are relatively backward in regional differentiation.

Table 4. Average index of population urbanization and economic development of each city in the Yangtze River Delta urban agglomeration from 2009 to 2020

City	Average Index of Population Urbanization	Average Index of Economic Development
Shanghai	0.8342	0.6941
Nanjing	0.4456	0.2659
Wuxi	0.4255	0.2492
Changzhou	0.3601	0.1770
Suzhou	0.4738	0.3538
Nantong	0.3174	0.1737
Yancheng	0.2529	0.1188
Yangzhou	0.2731	0.1362
Zhenjiang	0.3049	0.1350
Taizhou	0.2791	0.1258
Hangzhou	0.4116	0.2844
Ningbo	0.3872	0.2627
Jiaxing	0.3365	0.1362
Huzhou	0.2561	0.1095
Shaoxing	0.3028	0.1448
Jinhua	0.2949	0.1273
Zhoushan	0.2770	0.0993
Taizhou	0.2936	0.1140
Hefei	0.3046	0.1664
Wuhu	0.2113	0.1129
Ma On Shan	0.2190	0.0931

Tongling	0.1965	0.0813
Anqing	0.1241	0.0621
Chuzhou	0.1414	0.0700
Chizhou	0.1102	0.0549
Xuancheng	0.1339	0.0695

3.2.2 Spatial pattern analysis of coupling coordination degree

To further analyze the coupling coordination degree and spatial differentiation characteristics of population urbanization and economic development in each city of the Yangtze River Delta urban agglomeration, the years 2009, 2013, 2017, and 2020 are selected as representative years to calculate the coupling coordination degree values of 26 prefecture-level cities in the Yangtze River Delta urban agglomeration into ArcGIS 10.5 for spatial distribution map. From the global space (Figures 3 and 4), the level of coupling coordination between regional population urbanization and economic development is optimized continuously.

(1) Low coupling coordination areas are mainly distributed in northern Jiangsu, southern Zhejiang, and southern Anhui, and the number of cities is generally decreasing. In 2009, this type of area included 11 cities including Yancheng, Zhoushan, Taizhou, Wuhu, Chuzhou, Anqing, and Chizhou. Wuhu, Tongling, Huzhou1, and Jinhua changed from low coupling coordination areas to moderate ones in 2013. In 2017, Tongling evolved into this type, and other cities did not change. There were five cities of this type. In 2020, Tongling, Anqing, Chizhou, and Chuzhou turned into moderate coupling coordination areas, and there was only one city in this type, Chizhou.

(2) The number of cities in the moderate coupling coordination area is the largest and has not changed significantly. In 2009, there were 14 cities in this type of area, including Nanjing, Wuxi, Ningbo, and Hefei. In 2013, Nanjing, Wuxi, Suzhou, Hangzhou, and Ningbo changed from moderate coupling coordination to high coupling coordination. Yancheng, Wuhu, Tongling, Huzhou, and Jinhua evolved into this type with 16 other cities. In 2017, Tongling turned into a low-coupling coordination area with 15 other cities. In 2020, Chuzhou, Xuancheng, Anqing, and Tongling evolved into this type, and Hefei, Changzhou, and Nantong became high coupling coordination with a total of 16 cities in this type.

(3) The spatial pattern of the high coupling coordination area is roughly expanding and spreading, and the population urbanization and economic development of this type of area have gradually formed good coupling coordination. In 2009, there was only one city of this type, Shanghai. In 2013, Nanjing, Wuxi, Suzhou, Hangzhou, and Ningbo evolved into this type, and Shanghai turned into extreme coupling coordination, with a total of five cities in this type; in 2017, there was no change in the cities in high coupling coordination area. In 2020, Hefei, Changzhou, and Nantong evolved into this type, with a total of eight cities in this type.

(4) The spatial pattern of the extreme coupling coordination area is distributed in a "dot" shape, which indicates that the coupling coordinated development of population urbanization and economic development needs to be further optimized. In 2009, there were no cities in this type of area. In 2013, Shanghai evolved into this type, and there was no change in the cities of the extreme coupling coordination area in 2017 and 2020.
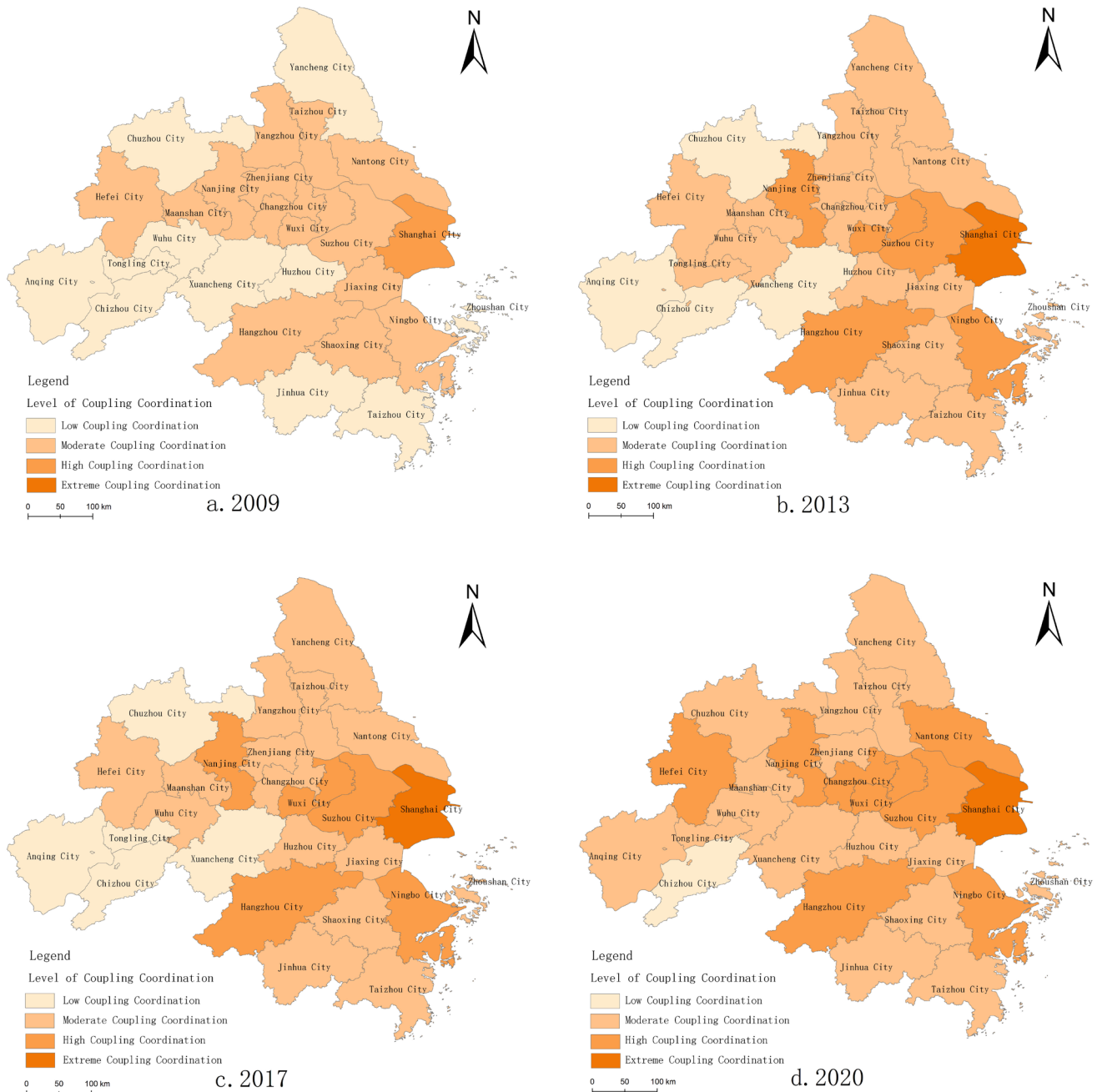
Figure 3. Spatial pattern of coupling coordination between population urbanization and economic development in the Yangtze River Delta urban agglomeration.

In terms of local space (Table 5), there is a clear polarization in the coupling coordination degree of population urbanization and economic development in the Yangtze River Delta urban agglomeration. Shanghai, Nanjing, Wuxi, Suzhou, Hangzhou, and Ningbo have been at the top of the coupling coordination level. Among them, Shanghai, as the central city of the Yangtze River Delta, has always been in the first position in terms of coordination, and Nanjing and Hangzhou have outstanding advantages as provincial capitals. Suzhou, Wuxi, and Ningbo have good industrial structures and high levels of population urbanization and economic development, so the population urbanization and economic development are more coordinated. Correspondingly, the cities with the lower ranking of coupling coordination degree of the Yangtze River Delta urban agglomeration have not changed much with Anqing, Chuzhou, Chizhou, and Xuancheng at the bottom for a long time. These cities are located on the mainland and

are far away from the provincial capital cities, so the improvement is slow, and the breakthrough is gradually made over time. However, its capital city Hefei has developed more rapidly in recent years, and its coupling coordination is comparable to that of Changzhou and other cities, fully reflecting the rapid development of central cities in the central region under the strategy of the rise of the central region in the new era.
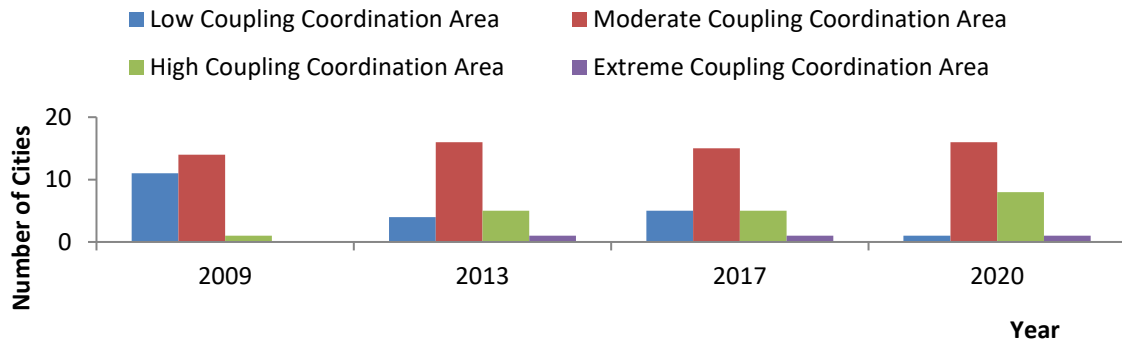

Figure 4. Evolution of the number of cities in the Yangtze River Delta urban agglomeration in terms of coupling coordination between population urbanization and economic development

Table 5. Coupling coordination degree and the average value of population urbanization and economic development in each city in the Yangtze River Delta urban agglomeration

City	2009	2013	2017	2020	Average
Shanghai	0.6812	0.8121	0.9315	0.9701	0.8487
Nanjing	0.3999	0.5234	0.6101	0.6642	0.5494
Wuxi	0.4367	0.5214	0.5743	0.6161	0.5371
Changzhou	0.3532	0.4359	0.4953	0.5269	0.4528
Suzhou	0.4988	0.6058	0.6721	0.7266	0.6258
Nantong	0.3379	0.4313	0.4917	0.5286	0.4474
Yancheng	0.2895	0.3656	0.3913	0.4211	0.3669
Yangzhou	0.3118	0.3851	0.4287	0.4571	0.3957
Zhenjiang	0.3197	0.3943	0.4221	0.4377	0.3934
Taizhou	0.3163	0.3628	0.4181	0.4433	0.3851
Hangzhou	0.4334	0.5266	0.6227	0.6745	0.5643
Ningbo	0.4473	0.5135	0.5933	0.6195	0.5434
Jiaxing	0.3017	0.3701	0.4348	0.4675	0.3936
Huzhou	0.2789	0.3365	0.3868	0.4152	0.3544
Shaoxing	0.3242	0.3974	0.4449	0.4725	0.4098
Jinhua	0.2989	0.3726	0.4158	0.4319	0.3798
Zhoushan	0.2749	0.3075	0.3555	0.4036	0.3354
Taizhou	0.2936	0.3475	0.3994	0.3979	0.3596
Hefei	0.3200	0.4087	0.4827	0.5273	0.4347

Wuhu	0.2915	0.3508	0.3894	0.4143	0.3615
Ma On Shan	0.3092	0.3295	0.3336	0.3697	0.3355
Tongling	0.2983	0.3390	0.2961	0.3022	0.3089
Anqing	0.1979	0.2515	0.2736	0.3039	0.2567
Chuzhou	0.2112	0.2592	0.2988	0.3556	0.2812
Chizhou	0.2194	0.2632	0.2373	0.2790	0.2497
Xuancheng	0.2228	0.2803	0.2942	0.3127	0.2775

4. Conclusions and Recommendations

4.1 Conclusion

Taking the Yangtze River Delta urban agglomeration as the research object, we construct the comprehensive evaluation index system of population urbanization and economic development and investigate the coupling coordination process and spatial pattern based on the entropy method and coupling coordination degree model. The final results show the following.

(1) On the whole, with the change of time, the comprehensive level of population urbanization and economic development of the Yangtze River Delta urban agglomeration is rising. Economic development lags behind the development of population urbanization, and the level of economic development needs to be further improved. At the same time, the coupling coordination degree of regional population urbanization and economic development is also rising from moderate coupling coordination to high coupling coordination. Compared with 2009, the synergistic development effect of the two is improved in 2020.

(2) The comprehensive level of population urbanization and economic development in the cities of the Yangtze River Delta urban agglomeration shows a significant inter-regional unbalanced development trend.

(3) There is obvious polarization in the coupling coordination level between population urbanization and economic development in the Yangtze River Delta urban agglomeration. Most of the regions have not yet reached a high degree of coupling coordination. There is only one city with high coupling coordination. The coordination level of Shanghai, Nanjing, Ningbo, and other cities is relatively high, while the development of Chizhou, Xuancheng, and other cities is relatively uncoordinated. To a certain extent, the result indicates that the deep integration of three provinces and one city is insufficient. On the whole, the coupling coordination degree of the Yangtze River Delta urban agglomeration still has great room for development in the future, and there is a long way to go to promote the coordinated development of various regions [13].

4.2 Recommendations

4.2.1 Improving the economic quality on time and narrowing the gap with the development of population urbanization

The level of population urbanization in the Yangtze River Delta urban agglomeration is significantly higher than that of economic development. Each city needs to make use of its advantages to timely improve economic growth, change the mode of economic development, adjust the part of the industrial structure that is not suitable for economic development, vigorously develop emerging technology industries, make overall arrangements and scientific planning, and adhere to the sustainable and stable development path to achieve the goal of coordinated and healthy development of population urbanization and economy.

4.2.2 Face up to regional differences and promote population urbanization and economic development.

Correct treatment of regional differences is required. Regional imbalance is common, and the imbalance of economic conditions, natural conditions, and other factors in different regions is outstanding. We cannot simply require the development of each city to reach the same level. From the perspective of dialectical thinking, it is necessary to promote relative balance in development. According to the theory of unbalanced development, developed regions are allowed to develop first, and economic wealth and regional industrialization experience can be accumulated in the region to have demonstration, incentive, and conduction effect on the backward regions, while also paying attention to the gap between the rich and the poor. In terms of policy, it is necessary to actively promote the development of regressing areas and form an integrated development plan through the joint efforts of the

market and the government. It is also needed to promote the development of regional backward areas with policy support, and accelerate the regional economic integration of the Yangtze River Delta urban agglomeration with the mind of the market[14].

4.2.3. Give full play to the effect of the metropolitan area and promote coordinated regional development.

Integrated development includes both vertical promotion of the regional overall level and horizontal coordinated development among regions. According to the research, the coupling coordination degree of population urbanization and economic development in Shanghai, Nanjing, Suzhou, Wuxi, and Hangzhou in the Yangtze River Delta urban agglomeration is relatively high. Shanghai is taken as the core metropolitan area, Nanjing, Suzhou, Wuxi, Hangzhou, Ningbo, and Hefei take the initiative to actively cooperate. On this basis, six metropolitan areas are constructed and positioned as the central growth pole, shaping a new pattern of high-quality integration, giving full play to its agglomeration effect, driving the economic development of surrounding cities, promoting the development of population urbanization by economic development, improving the level of coupling coordination, and promoting regional coordinated development.

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