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Article

Research on Coordinated Evolution of Economic and Logistics Coupling in Yangtze River Delta Region

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Abstract: Two subsystems in the economy and logistics are proposed to establish a comprehensive evaluation index system by using principal component analysis and the comprehensive weighted method. For 41 cities of the Yangtze River Delta cities, the economic development and the comprehensive score of the logistics system in 2003, 2008, 2013, 2017 are calculated, and through the analysis of the coupling coordination model, the economic system and coupling coordination degree of the temporal and spatial evolution process of the logistics system are investigated. The results show that the coupling coordination degree in the Yangtze River Delta region decreases gradually from the eastern coastal areas to the inland areas, and the coupling coordination degree is polarized in space.

Keywords: Regional Economy, Regional Logistics, Coupling Coordination, Yangtze River Delta Region

1. Introduction

Under the impetus of economic globalization and regional economic integration, the fast-growing economy drives the rapid growth of the logistics industry. At the same time, the regional logistics industry plays an increasingly important role in accelerating regional economic growth, promoting the upgrading of regional industrial structure, and improving regional comprehensive competitiveness. For a long time, the interaction between the logistics industry and the regional economy has attracted many scholars' interest in quantitative and qualitative research. The results show three different viewpoints. First, there is a relationship of mutual influence and mutual promotion between logistics and the economy. For research and development under the condition of the regional economic cluster effect, there is an interactive relationship between regional economy and logistics [1]. Based on the US zip code level data, Hylton et al. demonstrated that there is a long-term dynamic relationship between logistics clusters and economic agglomerations by improving spatial accuracy and controlling related variables in the statistical process [2]. In China, there is broad support for this view. Liu used system dynamics to simulate the dynamic correlation and coupling structure between regional logistics and economic growth and found that there was an adaptive adjustment between regional logistics and economic growth and the long-term moderate advance of logistics could improve the regional economic growth rate [3]. Ji took Yunnan province as an example to analyze the relationship between regional logistics and its economy. He pointed out that they promote each other to some extent and cities with a high level of economic development have a strong driving effect on the development of logistics in neighboring regions [4]. Li and Li studied the interaction between logistics and economy in the Yangtze River Delta region and found that there has been a long-term interaction between the two [5]. Second, there is only a one-way influence between economic growth and logistics development. This view is based on two theories: the logistics-driven economy theory and the economy-pulled logistics theory. The theory of a logistics-driven economy mainly states that the development of logistics promotes the development of the economy, while the growth of the economy has no obvious effect on logistics. Carruthers et al. concluded that the prosperity of Singapore and Hong Kong depended on their past influence on modern times to a certain extent and investment in the logistics industry [6]. Melelldez analyzed the impact of the development of the logistics industry on the economy in Latin America and concluded that the construction and development of the logistics industry played a great role in the progress of the regional economy [7]. Rubén used the input-output method to study the impact of the development of the logistics industry on the economy in Arogon, Spain and concluded that the infrastructure investment of the logistics industry had a driving effect on the economic development [8]. Tang and Salah found that Asian logistics performance drove Asian economic growth [9]. In the economic pull logistics theory, economic growth is thought to promote the development of logistics. Shu's research results proved that economic development had

a positive impact on logistics growth [10]. Li analyzed the relationship between the logistics industry and economic growth in Guangdong, China, and concluded that there was only a one-way causal relationship between the two. There is a certain role in promoting the development of the logistics industry, but the role of the logistics industry in promoting economic growth is not significant [11]. Third, there is no obvious relationship or influence between economic growth and logistics development. This view has the least support. Maciulis et al. analyzed the impact of the logistics industry on the development of the regional economy and believed that the logistics industry has an impact on the competitive advantage of the regional economy from both positive and negative aspects [12]. He analyzed the data of Sichuan Province in China from 2003 to 2013, and the results showed that the development status of the regional logistics system and the economic system was constantly changing through the interaction mechanism, the coordinated development of the overall system is achieved, but the overall degree of coordination is low [13].

If there is a good coupling and coordination relationship between logistics and economy, both form a mutual promotion effect. However, urban development is affected by many factors, resulting in an extremely complex interactive coupling relationship between logistics development and economic growth. Then, with the interaction and coupling relationship between logistics and economy in different cities in the region, how the relationship changes over time needs to be investigated. To achieve this goal, by taking the Yangtze River Delta region as the research area, we aim to construct the evaluation index system of the economic system and the logistics system by using the principal component analysis and the comprehensive weighting method. Fo doing this, the comprehensive score of the economy and logistics of the cities in the Yangtze River Delta region is calculated. On this basis, the coupling coordination degree model is established to show the coupling relationship between regional economy and regional logistics in geographic space. Countermeasures and suggestions are also proposed for the coordinated development of the Yangtze River Delta regional economy and regional logistics.

2. Methods Index Selection and Data Sources

Based on the literature review [14,15] of the inner mechanism of the regional economy and regional logistics system and the principle of authenticity and availability of data, the economic development system is divided into subsystems of economic development scale and economic structure. 10 indexes are selected to reflect the comprehensive situation of regional economic development [16,17]. The regional logistics system is divided into subsystems according to the logistics development scale and logistics development potential, and 7 indexes are selected to reflect the comprehensive situation of regional logistics development [18]. Data in Tables 1 and 2 are obtained from the China urban statistical yearbook (2004–2018) and local statistical bulletins, covering 41 prefecture-level cities in the Yangtze River Delta Region.

Table 1. Evaluation index system of coordination between regional economy

Target layer	Index layer
Economies of scale	GDP
	Gross industrial output value
	Total retail sales of consumer goods
	Total import and export trade
	Total investment in fixed assets
Economic structure	Per capita GDP
	Proportion of Total Fixed Assets to GDP
	Ratio of secondary production to GDP
	The proportion of employment in the tertiary industry
	Local fiscal revenue

Table 2. Evaluation index system of coordination between regional logistics

Target layer	Index layer
Logistics scale	Total mileage of transportation
	Urban Logistics Employees
	freight
Logistics potential	Investment in logistics fixed assets
	Fixed broadband access
	Mobile phone users
	Logistics location entropy

3. Research methods

Principal component analysis (PCA) is a data analysis method that transforms a large number of highly correlated indicators into several independent and comprehensive indicators that reflect most of the information of the original variables by reducing the data dimensions [19,20]. We use PCA to construct the index system of the regional economy and logistics involved in several indicators that unavoidably exist a certain correlation. However, the analysis is complicated to choose variables due to multiple collinearities. Thus, PCA is used for dimension reduction analysis by extracting principal components, the score of the comprehensive weights. When each city has the I (I = 1, 2,... , n) prefecture-level units, k (k= 1,2... , m) principal component indicators, and the weight of each indicator is Wk, then,

$$A_i=\sum_{k=1}^{m} Wk * Rki \quad (1)$$

where A_i is the comprehensive evaluation score of the ith city, Rki is the standardized value of k index of the ith city, and Wk is the proportion of the variance contribution rate of the principal component in the total variance contribution rate.

The coupling coordination degree model is based on coordination theory and system theory. It measures the degree of harmony and consistency between systems or elements within systems in the development process and reflects the trend of systems from disorder to order [21] as well as the degree of coordinated development between systems. The coupling coordination degree model has been widely applied to the research on the relationship between social economy and ecological environment, urbanization, and land resources since it was put forward. The specific equations are as follows.

$$C = \sqrt{\frac{U_1 * U_2}{((U_1+U_2)/2)^2}} \quad , \ C \in [0,1] \quad (2)$$

$$D = \sqrt{C * (\alpha U_1 + \beta U_2)} \ , \ \alpha = \beta = 0.5 \quad (3)$$

where U_1 and U_2 represent the comprehensive evaluation scores of the regional economy and regional logistics, C is the coupling degree of the regional economy and regional logistics, D is the coupling coordination degree between regional economy and regional logistics, α and β are undetermined coefficients, defining regional economy to be consistent with the importance of regional logistics, so α=β=0.5 is taken. Based on the relevant research results [22], the system coupling and coordination degree are divided into 4 types and 10 types, respectively. The specific evaluation criteria are shown in Tables 3 and 4.

Table 3. Coupling grade classification standard

Coupling	Coupling level
[0,0.3)	Low level coupling stage
[0.3,0.5)	Antagonistic phase
[0.5,0.8)	Run-in phase
[0.8,1.0]	High level coupling stage

Table 4. Standard for grading coordination degree

CoordinationD	Coordination level
[0,0.1)	Extreme imbalance
[0.1,0.2)	Serious imbalance
[0.2,0.3)	Moderate imbalance
[0.3,0.4)	Moderate imbalance
[0.4,0.5)	Imminent imbalance
[0.5,0.6)	Barely coordinated
[0.6,0.7)	Primary coordination
[0.7,0.8)	Intermediate coordination
[0.8,0.9)	Well coordinated
[0.9, 1]	Quality coordination

4. Results and Analysis

The principal component analysis was used to process the economic and logistics system data of 41 cities in the Yangtze River Delta Region in 2003, 2008, 2013, and 2017. The comprehensive evaluation score of the economic and logistics development system of each city was calculated by comprehensive weighting.

From 2003 to 2017, the economic development level of the cities in the Yangtze River Delta rose, and the overall regional development gap was narrowed but the overall pattern did not change much. The pattern of economic development was in the shape of "Z", and on the whole, it presented the pattern of the central periphery with "Yangtze River Delta" as the core. There was no great change in the ranking of the comprehensive economic development scores of each city every year. The cities with higher comprehensive economic development scores over the years were Shanghai, Suzhou, Wuxi, Hangzhou, Ningbo2, and Nanjing. The cities with lower scores are Haozhou, Liuan, Suzhou, and Anqing. The economic development level of each city in northern Jiangsu improved significantly.

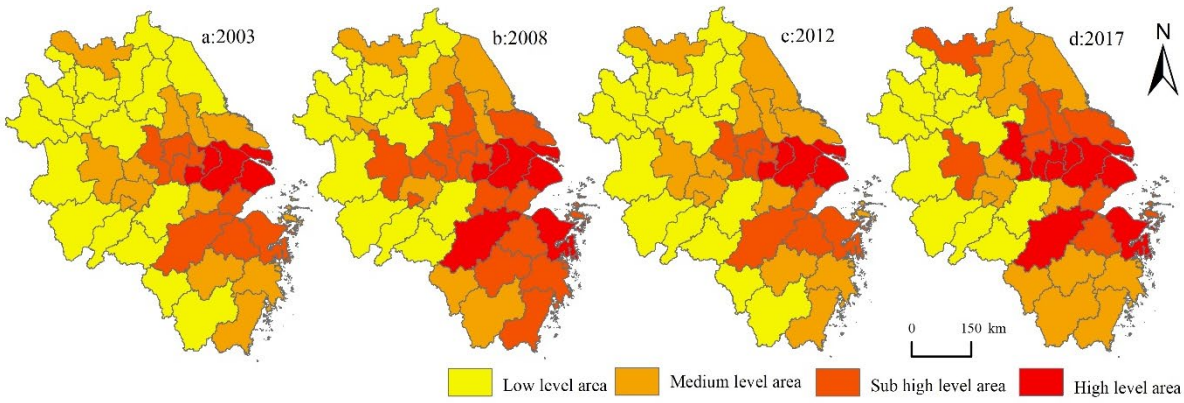

Figure 1. Evolution of spatial pattern of economy in Yangtze river delta region from 2003 to 2017.

The comprehensive evaluation score of the regional logistics development system showed that Shanghai had obvious advantages in logistics development level, while other cities generally had low comprehensive scores in logistics development. The average comprehensive scores of cities in the Yangtze River Delta region in 2003, 2008, 2013, and 2017 were 0.182, 0.202, 0.224, and 0.307, respectively. 40 cities of Anhui, Jiangsu, Zhejiang provinces had no obvious regularity in composite scores ranking distribution in regional logistics development. In the city's economic development level and city level of logistics development, there was no clear link. The level of logistics development was not high enough to affect economic development. Only the city's geographic location was important as a transportation hub and for transportation infrastructure development, as the logistics development of Suzhou in 2017 comprehensive score was lower than the average of 41 cities. Xuzhou showed the highest score in the Yangtze River Delta logistics development. However, there were cities with weak logistics development and economic development, such as Huangshan and Huaibei, related to the urban economic development model and industrial structure.

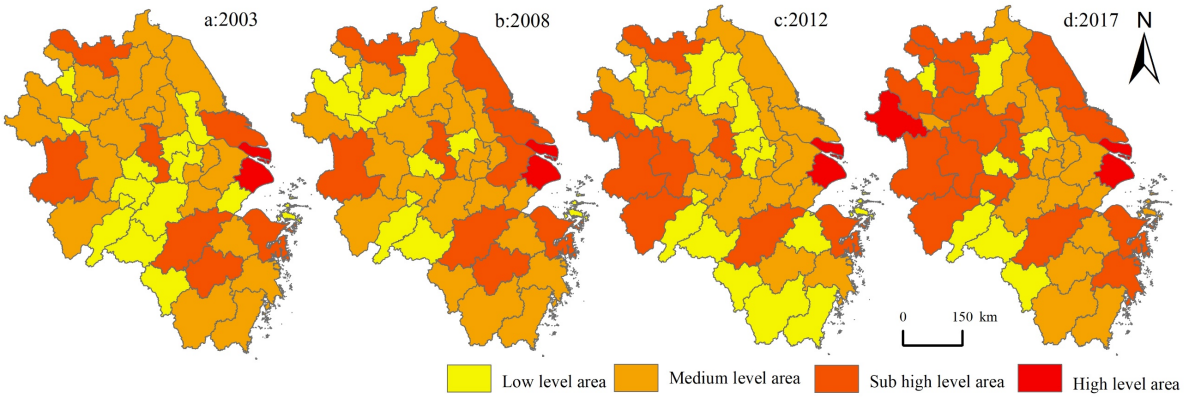

Figure 2. Evolution of spatial pattern of logistics development in Yangtze river delta region from 2003 to 2017.

Based on ArcGIS software, the coupling degree of cities in the Yangtze River Delta was visualized according to the coupling coordination classification standard. The spatial distribution pattern evolution of the coupling degree of economic and logistics systems in the Yangtze River Delta in 2003, 2008, 2013, and 2017 was obtained (Figure. 1). Shanghai was the city with the best coupling of economic system and logistics system among all the cities for 4 consecutive years. The cities in the west of Anhui, Fuyang, Tongling, Liu 'an, Haozhou, and others had low coupling degrees each year. The change in the spatial distribution of the coupling index showed that the cities with higher coupling degrees had a semi-circular distribution pattern with Shanghai as the center of the coastal distribution pattern. Cities in the Yangtze River Delta had a mutual influence on the two systems of the coupling relationship between economic development and the logistics industry but the impact was not enough to be the main reason for regional economic development. Thus, the logistics industry needs to grow with favorable development opportunities to increase the influence and relationship between the regional economy and logistics.

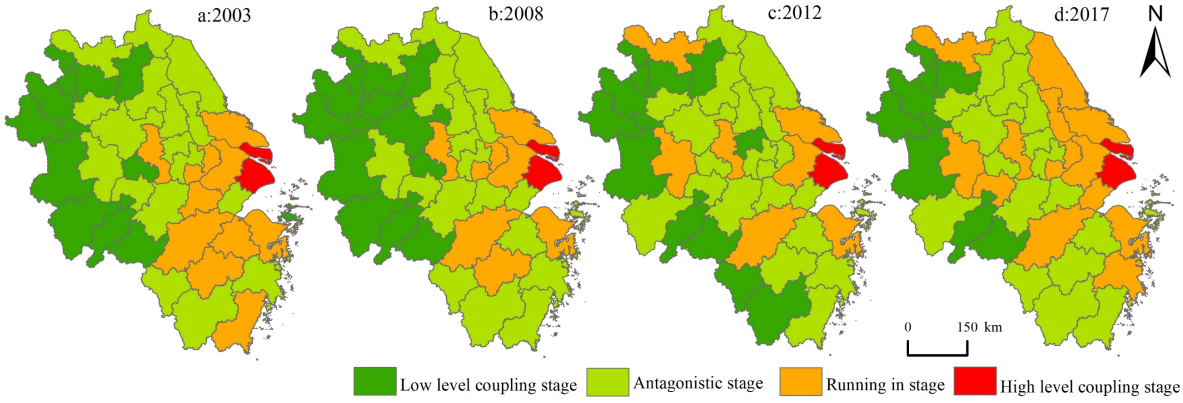

Figure 3. Evolution of spatial pattern of coupling degree of economy and logistics system in Yangtze river delta region from 2003 to 2017.

Based on ArcGIS software, the spatial pattern of coordination degree is classified according to Table 3 (Figure. 2). The coordination degree of economy and logistics systems in the Yangtze River Delta has gradually improved. Shanghai has always maintained a high degree of coordination. In 2003, the average degree of coordination in Zhejiang Province was higher than that in Jiangsu Province. By 2017, Jiangsu Province had a high degree of coordination. The score of coordination degree of each city in Anhui province was lower than that of the whole region. Due to the influence of Shanghai on the economic development of cities in the Yangtze River Delta, the coordination degree of economic development and logistics system in the Yangtze River Delta had gradually formed a dynamic force that was slowly optimized to the abdomen of the Yangtze River Delta in southern Jiangsu, central Jiangsu, Hangyong and eastern coastal cities. The coordination degree of Hangzhou, Suzhou, Ningbo, Nanjing, and other cities also showed a high degree of coordination in the region.

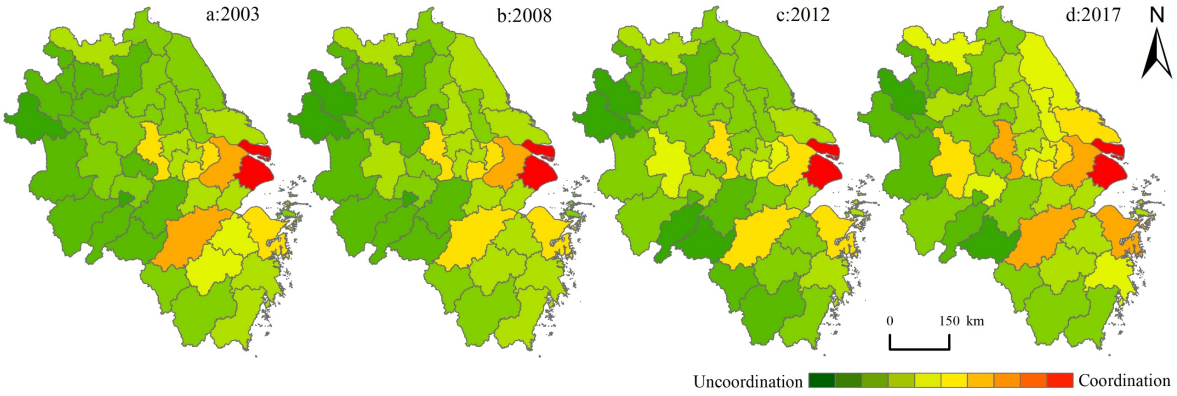

Figure 4. Evolution of spatial pattern of coordination between economy and logistics system in Yangtze river delta region from 2003 to 2017.

5. Discussion and Suggestions

(1) The economic development and logistics development of the city are mutually reinforcing. Because a developed economy produces a large number of goods, transporting these goods promotes the development of the logistics industry. Similarly, a well-developed logistics industry promotes the accumulation of various types of goods that are beneficial to economic development in cities, thereby promoting economic development. For example, Shanghai is the city with the strongest regional economic development and the highest level of logistics development. Logistics and the economy have formed a good interactive relationship.

(2) The status or ranking of urban economic and logistics development levels in the region may be inconsistent. Since the regional economy includes different types of industries, the logistics industry is only a part of it, so there is a mismatch between the economic development level of the city and the level of logistics development. Several cities have good economic development, but the level of logistics development is relatively low. For example, Zhenjiang in Jiangsu Province ranks high among the Yangtze River Delta cities in terms of economic development level, but the logistics level is lower. Several cities have relatively underdeveloped economies but the level of logistics development is relatively good such as cities in northern Anhui Province. The corresponding relationship between the two is mainly related to the proportion of the logistics industry in the regional economy.

(3) The spatial pattern of the coupling and coordination relationship between the economic and logistics development levels in the Yangtze River Delta region and the spatial pattern of economic development show two possibilities. One is that there are many location factors required for economic development. These factors also make logistics develop well in more developed cities in the region. With better development, a city has better coupling and coordination. Second, although economic development and logistics development promote each other, the development of the two is affected by a variety of factors, which makes the development status of the two constantly change and difficult to synchronize. This asynchronous phenomenon is observed at the development level. This is consistent with He's finding that the overall synergy between regional economy and logistics is low [15].

Logistics development also needs to further improve operational efficiency, strengthen regional cooperation and coordination in the logistics industry and realize the benign and coordinated development of regional logistics and regional economy.

(1) Strengthen the interaction and development of regional economy

If the Yangtze River Delta wants to rapidly and stably realize the overall improvement of its economic strength, it needs to break down administrative division barriers and set up an organization that belongs to the whole Yangtze River Delta and is responsible for managing and coordinating the economic development. For example, to promote coordinated economic development between the pearl river delta, Hong Kong and Macao, 'Mainland and Hong Kong Closer Economic Partnership Arrangement' (CEPA) was implemented in 2004. For the Yangtze River Delta, it is necessary to establish a similar institution to be responsible for coordinating the economic and social development of the whole Yangtze River Delta region, promoting the rational industrial layout of the whole Yangtze River Delta region, and upgrading the industrial structure. Of course, while improving and optimizing the industrial structure in the east, the central and western regions need to examine their positions

in the Yangtze River Delta, strengthen strategic cooperation among regions and take advantage of the development, and strive to promote major project construction, industrial structure adjustment, energy conservation and emission reduction and livelihood projects. For example, under the influence of the radiation from Shanghai and southern Jiangsu, Anhui exerts greater influence in the central Anhui region and thus spreads the economic driving effect of the central region to western, northern, and southern regions. Anhui realizes regional economic development synergy, encourages the creation of characteristic industries of various cities, and strengthens the strategic interaction and mutual influence among regions.

(2) Promote the development of logistics in the Yangtze River Delta
Each city needs to carry out the input of logistics resources based on the local economic development level and demand and improve the construction of logistics infrastructure. For cities whose logistics development lags behind economic development, a new pole of logistics growth need to be built according to the direction of economic development, a modern logistics industry should be developed, informatization and standardization of the logistics industry should be promoted, and logistics should play its accelerating and boosting role in economic development by balancing the supply and demand of logistics in cities. For cities where logistics is ahead of economic development, the large gap between logistics and economic development does not help the region improve the efficiency of the use of logistics resources although a proper advance in logistics has a positive effect on the economic development of the city. On the contrary, it may lead to repeated construction and affect the economic development of the city. Thus, such a city should adjust the logistics industry structure according to the economic development policy and level while accelerating the economic development level and speed. Cities with relatively poor logistics development and economic development should establish regional logistics networks to achieve sustainable development based on the construction of logistics infrastructure, sharing of logistics resources and sharing of logistics policies throughout the region.

6. Conclusions

Through theoretical analysis, we studied the coupling coordination degree between the regional economic development and the logistics system of 41 prefecture-level cities in the Yangtze River Delta from 2003 to 2017. The study is based on the construction of the comprehensive evaluation index system of the two subsystems of economy and logistics. The coupling coordination degree model was constructed with the comprehensive evaluation index system of the two subsystems of economy and logistics. Principal component analysis and weighting were used to calculate the comprehensive scores of multiple indexes of the two systems. The research results are summarized as follows.

(1) The coupling and coordination degrees of economy and logistics in the Yangtze River Delta are constantly improving, and Shanghai had the best coupling and coordination degree among all the cities for four years. The distribution pattern of cities with a high degree of coupling changed from a semi-circular pattern centered on Shanghai in 2003 to a coastal area in Zhejiang province. The score of coordination degree of each city in Anhui province was lower than that of the whole region. The coordination degree of economic development and logistics system in the Yangtze River Delta was extended to the abdomen of the Yangtze River Delta with the east as the driving force.

(2) The city's economic development and logistics development are mutually reinforcing. However, the status or ranking of urban economic and logistics development levels in the region may be inconsistent. The spatial pattern of coupling and coordination of the economy and logistics in the Yangtze River Delta region was close to the spatial pattern of economic development.

(3) In order to realize the benign coordinated development of regional logistics and regional economy, it is required to strengthen the interactive development of the regional economy and promote the development of logistics in the Yangtze River Delta.

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