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The Structure of the Overall Network of Research on Spatial Correlation Network Structure and Effects of Regional Logistics

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Abstract:

Based on the panel data of provinces in the Yangtze River economic Belt from 2007 to 2017, this paper evaluates the regional logistics quality index based on the entropy weight TOPSIS method, and uses the modified gravity model to measure the spatial correlation degree of regional logistics, the social network analysis is used to analyze the regional logistics spatial correlation network structure characteristics, and the effect of spatial correlation networks structure of regional logistics is studied through individual network characteristics. The results show that the regional logistics spatial correlation are constantly strengthened among provinces in the Yangtze River Economic Belt, but the cooperation among provinces still needs to be strengthened; Shanghai, Jiangsu, Zhejiang, Hubei and Chongqing are at the center of the network and play a leading role in the network; the improvement of relative degree centrality, relative closeness centrality and relative betweenness centrality of individual network, which have positive effects on the inter regional logistics quality and the effect of spatial correlation networks structure of regional logistics.

Keywords:*Regional logistics, Spatial correlation, Social network analysis, Network structure effect, Yangtze River Economic Belt*

I. INTRODUCTION

Regional logistics is an essential part of the regional economy, and the connection and flow of various elements in the region need to be completed with the help of logistics. Due to the long-term existence of gradient gaps in logistics development resources in the eastern, central and western regions of my country, the regional logistics development is unbalanced. Contributing to the regional logistics coordinated development has become an crucial focus of the current top-level design of the logistics industry. Along with the advancement of regional

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economic integration, regional logistics has surpassed the traditional linear development model, presenting a complex spatial association network structure. Accordingly, an in-depth study of the structural features and effects of regional logistics spatial correlation network has important theoretical significance and application value for contributing to the regional logisticscoordinated development.

The discussion on the spatial association mechanism of regional logistics is gradually deepening. From the existing research, it has generally experienced such a continuous expansion process of points, lines and networks [1,2]. "Point" is the gathering place of regional logistics. Through the preferential growth of regions with "growth poles", the common prosperity of neighboring regions can be promoted. Based on this perspective, some scholars have studied the agglomeration effect of regional logistics [3,4], and found that key logistics nodes will produce a certain degree of spatial spillover effect. In the 1980s, the "point-axis development theory" proposed by Professor Lu Dadao was an extension of the "growth pole theory" [5]. It was a concentrated expression of the spatial linear advancement in theregional economic developmentprocess, in order to correlate regional logistics spatial. The research of "Axial-spoke" logistics channel is mainly constructed by evaluating the level of urban logistics industry and determining the scope of radiation [6]. Its research area is mainly concentrated in the Yangtze River Delta [7] and the Yangtze River coast area [8]. It is precisely because of the regional flow of logistics development elements that the logistics resources in the region are connected by dots and lines to form a logistics network. The regional logistics network has huge logistics economic attractiveness and radiation power, and is an advanced stage of the coordinated development of regional logistics. Currently, the study on regional logistics network emphatically concentrated in the research of logistics enterprise spatial organization network [9, 10] and the research of logistics network characteristics [11].

Regarding the choice of empirical methods for regional logistics spatial correlation, some scholars use gravity models to measure the strength of regional logistics connections [12,13]; some studies about the characteristics of regional logistics spatial correlation networks through social network analysis [14,15], there are also methods such as location entropy and location Gini coefficient to describe the spatial pattern and improvement process of regional logistics clusters [16,17]; in addition, scholars use econometric methods to build panel data models to influence the impact factors are studied [18,19], or based on "relational data" through the Quadratic Assignment Procedure (QAP) method for driving mechanism research [20].

The above-mentioned research has achieved fruitful results, but there is still room for expansion. First, there are many studies on the eastern coastal provinces and cities and urban agglomerations[21,22], and there are relatively few studies on the Yangtze River Economic Belt, an crucial economic development region. Second, existing studies are more focus on "attribute data "Describe the structure characteristics of regional logistics spatial network, less research on the overall spatial correlation characteristics based on "relational data", ignore the "relationship" between nodes, and fail to reveal the effect of the "relationship" on the operation

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of the network. Third, existing research mainly focuses on the region Research on the features of thelogistics spatial correlation network[23], while the analysis about the structural effects of the spatial correlation network of regional logistics is relatively lacking. This paper takes the Yangtze River Economic Belt that spans the east, middle and west of China as an example. By constructing the logistics quality evaluation index system of the Yangtze River Economic Belt, the entropy TOPSIS method is used to evaluate the logistics quality of the Yangtze River Economic Belt. The economic distance between provinces and cities in the Yangtze River Economic Belt and the characteristics of water transportation are emphasized to highlight the particularity of regional logistics in the Yangtze River Economic Belt. The social network analysis method is used to construct the logistics spatial correlation network diagram to conduct overall and individual networks characteristic research, and building block model for sector role analysis.Finally, based on the above individual network characteristics analysis results, the structure effect of logistics spatial associated network was analyzed, so as to reveal the overall layout and evolution of logistics spatial associated network, and provide suggestions for promoting the coordinated development of logistics among provinces and cities.

II. MATERIALS AND METHODOLOGY

2.1 Construction of Regional Logistics Spatial Correlation Model

The establishment of the relationship is the key to the analysis of the spatial association network of regional logistics. The existing literaturemostly includes the gravity model and the Granger causality test to determine the spatial association relationship. Among them, the gravity model has the advantages of being suitable for total data and comprehensively considering economic and geographical factors. Therefore, this article applies the gravity model to the study of the spatial relationship of logistics in the Yangtze River Economic Belt.

(1) Improved gravity model. The gravity model stem from Newton's law of universal gravitation in physics. Since Zipf [24] applied the gravity model to the analysis of urban spatial interaction, this model has been widely used in economics and other fields. The gravity model is usually expressed as:

$$I_{ij} = k\frac{M_i M_j}{d_{ij}^r} \quad (1)$$

In Equation (1): I_{ij} is the gravitational value between regions i and j, d_{ij} is the distance between regions i and j, M_i and M_j are certain social and economic "quality" of regions i and j, and k is the gravitational coefficient, R is the gravitational attenuation index. Considering that it is difficult for a single incremental index and spatial distance of the logistics industry to fully reflect the connotation of "quality" and "distance", based on the existing literature [25,26], the gravity model is improved, and the logistics gravity coefficient "k"is taken as a value is 1, the gravitational attenuation index "r"is set to 2, and the improved regional logistics gravity model is:

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$$\begin{cases} I_{ij} = M_i M_j / d_{ij}^{\ 2} \\ d_{ij} = \sum_{f=1}^{3} \lambda_f (D_{ijf} \cdot C_{ijf} \cdot T_{ijf})^{1/3} \\ \lambda_f = (F_{if} + F_{jf}) / (\sum_{f=1}^{3} F_{if} + \sum_{f=1}^{3} F_{jf}) \end{cases} \tag{2}$$

Where, I_{ij} represents the value of the logistics correlation between areas i and j, M_i and M_j represent the logistics quality of areas i and j, d_{ij} represents the economic distance between areas i and j; f represents the mode of transportation used between the two areas (Among them, f=1 means road transportation; f=2 means railway transportation; f=3 means water transportation); λ_f means the weight of transportation mode f; D_{ijf} means transportation mileage of transportation mode f between area i and j; C_{ijf} means the transport rate of transport mode f between areas i and j; T_{ijf} represents the shortest transport time of transport mode f between areas i and j; F_{if} and F_{jf} represent the freight volume of transport mode f between areas i and j.

(2) Determination of regional logistics quality evaluation methods. The evaluation of logistics quality is a multi-objective comprehensive evaluation. Taking into account the logistics characteristics of 11 provinces and cities, this research selects a highly objective valuation method, combining the advantages of entropy weight method and TOPSIS method, and adopts entropy weight TOPSIS method to evaluate regional logistics quality [27].

(3)Social network analysis, also known as structural analysis, it is a set of theories and methods to analyze the structure and attributes of social relations. It mainly analyzes the relationship structure and attributes formed by different social units (individual, group or society). Social network analysis mainly includes the analysis of overall network characteristics and individual network characteristics, as well as the analysis of regional logistics spatial correlation spillover paths through block models. This paper specifically draws on the calculation methods of Shao Hanhua et al. [28] and Liu Huajun et al. [29].

2.2 Indicator Construction and Data Description

Construction of regional logistics quality index system. Based on the findings of regional logistics quality in related literature [30-32], considering the availability, comparability and representativeness of data, this article builds regional logistics quality from three aspects: economic development level, logistics supply and demand scale, and logistics infrastructure. The evaluation index system is displayed in TABLE I. Among them, in the logistics infrastructure indicator layer, the practice of Ma Yueyue [33] is used for reference, and the density of transportation lines is used to characterize the hardware support of logistics infrastructure.The calculation method of traffic line density as follows: First, convert the freight turnover of railways, highways and waterways into a comprehensive turnover. Secondly, calculate the transportation capability per 10,000 km, transportation capacity per 10,000 km = comprehensive turnover/operating mileage. Then calculate the total highway mileage, total

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highway mileage = railway mileage ×(railway transportation capacity/highway transportation capacity) + waterway mileage × (waterway transportation capacity/highway transportation capacity) + highway mileage. Finally, calculate the ratio of total highway mileage to administrative area of each province, namely the traffic line density of each province, unit: km/km^2.

TABLE I. Regional logistics quality evaluation index system

Target layer	Criterion layer	Index layer
Logistics quality	The level of economic development	Regional GDP per capita (yuan) The added value of the tertiary industry accounts for the proportion of regional GDP (%)
	Logistics supply and demand scale	The added value of logistics industry accounts for the proportion of regional GDP (%) Freight volume per capita (tons/person) Per capita total retail sales of consumer goods (yuan/person) Number of employees in the logistics industry (person)
	Logistics infrastructure	Traffic line density (km/km2) Per capita post and telecommunications business volume (yuan/person) Per capita mobile phone ownership (household/person)

Data specification. In 2006, the national "Eleventh Five-Year" planning outline put forward the strategic plan of "developing modern logistics industry vigorously", marking that my country's modern logistics has entered a fast-developing period. At the same time, taking into account the analysis of spatial correlation network structure effect, the statistics of the index data of "local fiscal transportation expenditure" began in 2007, and the index data of various provinces and cities in the Yangtze River Economic Belt from 2007 to 2017 are used for analysis. In order to eliminate price differences, with 2007 as the base period, the regional GDP per capita, the added value of the tertiary industry, and the added value of the logistics industry will be deflated by the GDP index of each province and city. The data comes from the *China Statistical Yearbook*, *China Population and Employment Statistical Yearbook* and the statistical yearbooks of provinces and cities in the Yangtze River Economic Belt.

In addition, for the convenience of research, the measurement of the economic distance of the logistics spatial correlation between provinces and cities are set as follows: the waterway mileage only considers the distance between important ports in the provinces and cities on the Yangtze River (the ports include Shanghai Port and Nanjing Port, Wuhu Port, Jiujiang Port, Wuhan Port, Yueyang Port, Chongqing Port and Luzhou Port. For the three provinces of Zhejiang, Guizhou, and Yunnan that have no ports on the main stream of the Yangtze River, the nearest port in the main stream of the Yangtze River is selected as the nearest port. Its water transport enters and exits ports. The important ports in the main Yangtze River corresponding to these three provinces are Zhenjiang Port, Fuling Port, and Yibin Port).The determination of waterway transport speed and time draws on the setting method of Huang Qiang [34], the transportation speed of the mainstream of the Yangtze River is set to 18km/h, the waterway transportation time is obtained by dividing the channel mileage between the ports by the corresponding transportation speed. Road transportation mileage and time are derived from Baidu navigation map (http://www.ditu6.com/bd/), select the shortest traffic mileage and corresponding traffic time for inter-city driving. The length and time of railway transportation, the capital cities of the two provinces and cities are selected as the starting and terminal stations, and high-speed railways are given priority, which can be obtained through the information query of China Railway 12306 (https://www.12306.cn/index/view/infos/jiaotong.html).The road transport rate is 1.5, the railway transport rate is 1, and the waterway transport rate is 0.5 [8].

III. DATA ANALYSIS

3.1 Analysis of the Structural Characteristics of the Logistics Spatial Correlation Network

3.1.1 Overall Network Structure Characteristics and Evolution Trend

According to the improved gravitational model, the spatial correlation of logistics between provinces and cities is determined, the relationship matrix is established, and the average value of each row in the relationship matrix is taken. If a certain element value in the relationship matrix is greater than the average value of the row, then take 1; otherwise, take 0 to obtain the asymmetric 0-1 matrix of the spatial association network. The matrix was imported into Ucinet 16.0 software, and the visualization tool Netdraw was used to draw the spatial association network diagram of logistics in the Yangtze River Economic Belt in 2007, 2012 and 2017 by using the isometric observation method (as shown in Fig 1), and calculates the changes in the number of network correlations, network density, network level, and network efficiency from 2007 to 2017 trend (as shown in Fig 2 and Fig 3). In addition, the calculation shows that the logistics network relevance of the Yangtze River Economic Belt from 2007 to 2017 is 1, which indicates that the network is highly accessible and the logistics development links between provinces and cities are close.

It can be known from Fig 1 that the spatial association of logistics in the Yangtze River Economic Belt presents a relatively typical network structure. Taking 2017 as an example, the regional logistics of the Yangtze River Economic Belt has a total of 41 spatially related channels, and each province and city has at least one spatially related relationship, and most provinces and cities have spillover relationships and beneficial relationships, indicating that the development of logistics is generally related in spatial, and the development of logistics in various provinces and cities influences each other. In addition, regions with many spatial associations, such as Shanghai, Jiangsu, Zhejiang, Hubei and Chongqing, etc., are in the core region and the middle position of the network, and have relatively dense spatial associations

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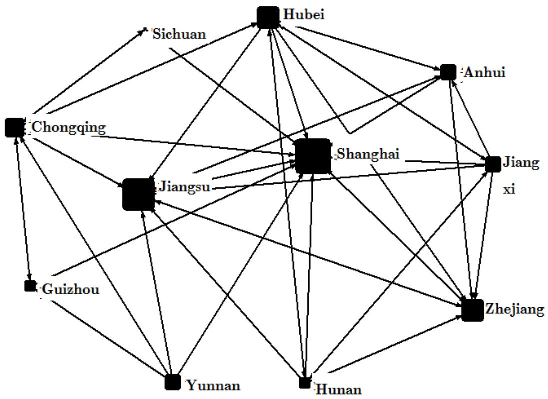
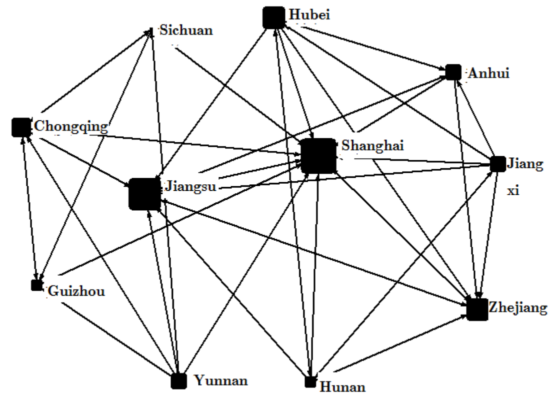
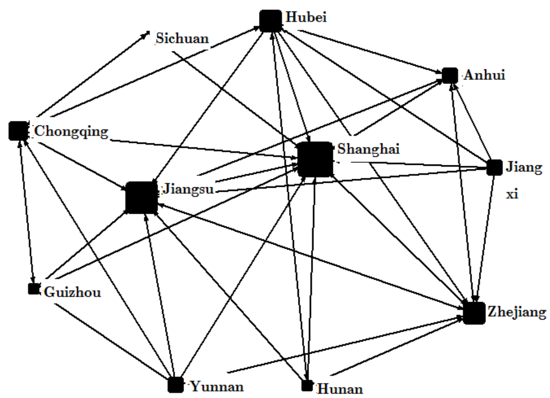
with other regions, which have obvious radiation and diffusion effects on other peripheral provinces and cities. Regions with little spatial correlation, such as Hunan, Sichuan, Guizhou and Yunnan, are mainly at the edge of the network map.



a.2007



b.2012



c.2017

Fig 1: The spatial correlation network of logistics in the Yangtze River Economic Belt in 2007, 2012 and 2017

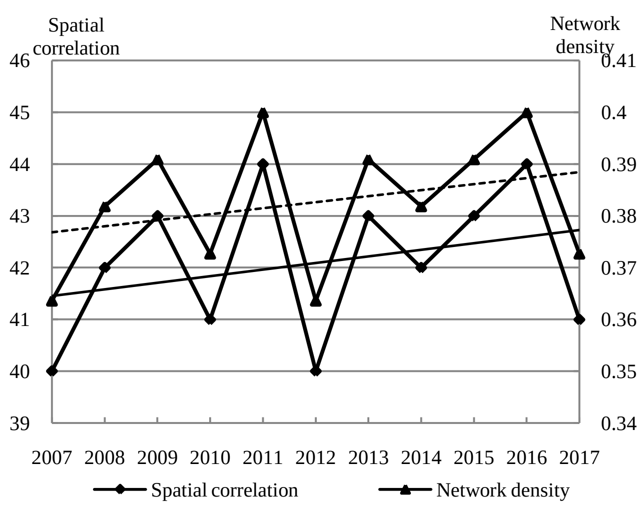


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Fig 2: The number of spatial correlations and network density of logistics in the Yangtze River Economic Belt

Figure 2 reflects the changes of various indicators of logistics spatial correlationduring the sample investigation period. On the whole, the number of spatial correlations between provinces and cities during the sample investigation period showed an upward trend, but the relevant year showed certain fluctuations. For example, the number of associations in 2009 was 43, fell to 40 in 2012, and rose to 44 in 2016. The maximum possible number of relationships among 11 provinces and cities is 110 (11×(11-1)), while the actual number of relationships between provinces and cities during the sample investigation period is only 44. Therefore, promote the logistics spatial correlation between provinces and cities, there is still a large space for improvement. Correspondingly, the network density also shows a similar trend, from 0.391 in 2009 to 0.362 in 2012, and then back to 0.400 in 2016, indicating that the closeness of logistics spatial correlation fluctuates slightly in the rise. The changes in the network density and the number of correlations indicate that the logistics links between provinces and cities in the Yangtze River Economic Belt are complex and close, but at the same time they have volatility characteristics, and there is a lot of room for improvement.

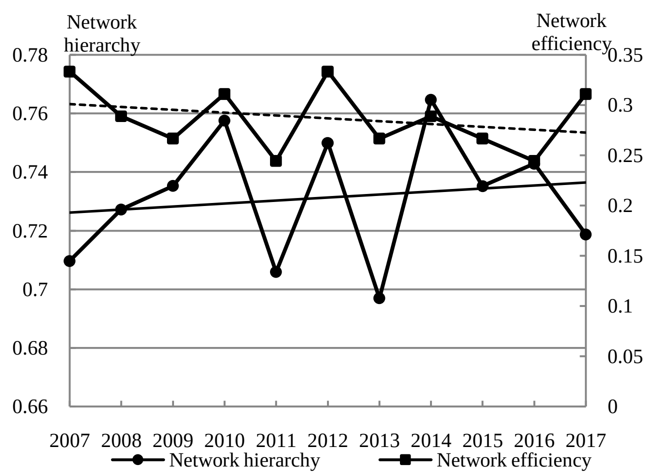

Fig 3: The level and efficiency of the logistics spatial correlation network in the Yangtze River Economic Belt

Fig 3 presents the network relevance, network level, and network efficiency. It can be known from the figure that during the sample period, the level of whole network is on the rise, but it shows a certain degree of volatility, indicating that the relatively strict spatial association structure of logistics still needs to be further broken, and the interconnection and mutual influence of logistics between provinces and cities need to be further strengthened. The network efficiency measurement results indicate that the overall network efficiency of the logistics industry in the region during the sample investigation period has shown a downward trend, which shows that the overall connection in logistics spatial correlation network is increasing as a whole, and the overall stability of the network is gradually increasing.

3.1.2 Centrality Analysis

This paper conducts a centrality analysis by measuring relative degree centrality, relative proximity centrality, and relative intermediate centrality (see TABLE II) to determine the status and role of each province and city in the spatial correlation network of the logistics industry.

TABLE II. Analysis of the centrality of the logistics spatial correlation network of the Yangtze River Economic Belt in 2017

Province	Relative degree centrality				Relative closeness centrality		Relative betweenness centrality	
	In-degree	Out-degree	Index(%)	Rank	Index(%)	Rank	Index(%)	Rank
Shanghai	10	3	100.000	1	100.000	1	24.815	1
Jiangsu	9	3	90.000	2	90.909	2	11.481	2
Zhejiang	7	3	70.000	3	76.923	3	3.889	4
Anhui	5	3	50.000	6	66.667	6	0.000	7
Jiangxi	0	5	50.000	7	66.667	7	0.000	8
Hubei	3	5	70.000	4	76.923	4	3.889	5
Hunan	1	4	40.000	9	62.500	9	0.000	9
Chongqing	3	5	60.000	5	71.429	5	5.741	3
Sichuan	1	2	20.000	11	55.556	11	0.000	10
Guizhou	2	3	40.000	10	62.500	10	0.000	11
Yunnan	0	5	50.000	8	66.667	8	1.296	6
Mean	3.727	3.727	58.182	—	72.431	—	4.646	—

Relative degree centrality. It can be known from TABLE II that the relative degree centrality of Shanghai, Jiangsu, Zhejiang, Hubei, and Chongqing is higher than the average. These provinces and cities have a large number of relationships with other provinces and cities in the logistics spatial association network. Among them, the relative degree centrality of Shanghai is up to 100%. The reason is that Shanghai's logistics industry has spatial associations and spaces between the other 10 provinces and cities. Overflow shows that Shanghai is so central to the logistics spatial association network in the Yangtze River Economic Belt. Of the above five provinces and cities, except Chongqing, they are all located in the middle and lower reaches of the Yangtze River, indicating that the middle and lower reaches of the Yangtze River have a strong influence on the logistics spatial correlation and spatial spillover effects of the Yangtze River Economic Belt. The last three places in terms of relative degree centrality are Hunan, Sichuan, and Guizhou, indicating that the logistics development of these provinces and cities has less relationship with other provinces and cities. The reason may be that they have a larger logistics scale than other provinces and cities. The location is relatively remote, resulting in a weak spatial relationship between its logistics and other provinces and cities.

It can be further known from TABLE II that from the point-out degree and the point-in degree, the five provinces and cities with the point-out degree greater than the average value of

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3.727 are Jiangxi, Hubei, Chongqing, Yunnan and Hunan. The logistics development of these provinces and cities has a strong spillover effect on other provinces and cities, and the point-out rate of these provinces and cities remains between 4 and 5, indicating that the spillover effect of the logistics development of various provinces and cities does not stop at neighboring provinces and cities. The spatial spillover of logistics has crossed the constraints of geographical proximity, and has formed a broader relationship throughout the Yangtze River Economic Belt. Shanghai, Jiangsu, Zhejiang, and Anhui with higher click-through rates. The reason is that most of these provinces and cities belong to the economically developed areas of the lower reaches of the Yangtze River. They have relatively large logistics markets and are more attractive to logistics resources and factors. The development of internal logistics has benefited more, and the "Matthew Effect" of logistics is obvious.

Relatively close to centrality. It can be seen from TABLE II that Shanghai, Jiangsu, Zhejiang, Hubei, and Chongqing are relatively close to the center of the Yangtze River Economic Belt, which shows that these provinces and cities act as the central actors in the logistics spatial correlation network. Create internal connections with other provinces and cities faster. The reason is that these provinces and cities have a relatively high level of economic development, are more efficient in logistics flows with other provinces and cities, and have a strong ability to obtain logistics resources and elements, which have an essential impact on driving the development of logistics in other provinces and cities. Hunan, Sichuan, and Guizhou are relatively close to the centrality. This may be due to the lower economic development level of these provinces and cities than those in the middle and lower reaches of the Yangtze River. They are far away from other provinces and cities in the logistics spatial correlation network. The ability to develop resources is weak, and it plays the role of marginal actor in the network, which is not conducive to its benefit in the logistics spatial correlation network.

Relative betweenness centrality. It can be seen from TABLE II that the relative intermediary centrality of the provinces and cities in the logistics spatial association network is large and the imbalance characteristics are obvious. The regions with relative intermediary centrality higher than the average are Shanghai, Jiangsu, and Chongqing in order from high to low. The relative intermediary centrality of the three provinces and cities reached 24.815, 11.481 and 5.741 respectively, which was much higher than that of other provinces and cities, indicating that Shanghai, Jiangsu and Chongqing are in the core position of the upstream and downstream regions in the logistics spatial correlation network and take on a major role. The role of "bridge" and "intermediary". In addition, in 2017, the sum of the centrality of provinces and cities higher than the average of the relative intermediary centrality, accounting for 82.25% of the total. Most of these provinces and cities are located in areas with high levels of social development or better logistics development, with superior geographical locations and better ownership. The economic foundation and good infrastructure have a high control over the resources and elements required for logistics development. The last four provinces, Anhui, Jiangxi, Sichuan, and Guizhou, all have zero intermediary centrality, which is insufficient to control and dominate

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other provinces and cities in the network. These provinces and cities are divided into two categories: one includes Anhui and Jiangxi, and the other includes Sichuan and Guizhou. The former is at a disadvantage compared to other regions in terms of logistics scale and economic development. In addition, Jiangsu, which is adjacent to Anhui, has a strong core position in the lower reaches of the Yangtze River. This has led to Anhui's position in the local network and its control over resources have been weakened. The latter has a gap in economic development compared with other regions, and at the edge of the logistics spatial correlation network. The logistics relationship with other regions often needs to rely on the "intermediary" role of developed provinces and cities.

3.1.3 Block Model

In order to visually display the characteristics of each province and city in the logistics spatial association network of the Yangtze River Economic Belt, a block model is used to perform spatial clustering analysis. This research uses the CONCOR method, selects the maximum segmentation depth as 2, and the concentration standard as 0.2. Based on the 2017 data, the 11 provinces and cities are separated into four sectors (as shown in TABLE III).

TABLE III. Analysis of the spillover effect of the logistics spatial correlation sectors

Sector	Number of internal relations of the sector	Number of sector overflow relations	Receiving the number of external relations	Number of provinces and cities in the sector	Expected proportion of internal relations (%)	Actual internal relationship ratio(%)	Sector attributes	Provinces and cities in the sector
The first sector	12	12	19	4	30	100.00	Net benefit sector	Shanghai, Jiangsu, Zhejiang, Anhui
Second sector	3	14	1	3	20	21.43	Broker sector	Jiangxi, Hubei, Hunan
The third sector	1	10	2	2	10	10.00	Two-way overflow sector	Chongqing, Yunnan
Fourth sector	0	5	3	2	10	0.00	Net spillover sector	Sichuan, Guizhou

Note: The actual ratio of internal relations = the number of internal relations of the sector/the number of spillover relations of the sector × 100%; the ratio of expected internal relations = (the number of provinces and cities in the sector-1) / (the number of all provinces and cities in the network-1) × 100%.

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From the above calculation of the overall spatial correlation network, there are 41 correlations in the logistics spatial correlation network of the Yangtze River Economic Belt. The number of internal relations of the four sectors is 16, the number of external relations of the receiving sector is 25, and there are between sectors. Obvious spatial correlation and spillover effects. From to the analysis results in TABLE III, it can be known that the number of external relations received by the first sector is larger than the number of spillover relations. The four provinces and cities of this sector are mainly in the lower reaches of the Yangtze River, with a high level of logistics development and a large logistics market. The logistics of the middle and upper reaches of the provinces and cities overflow, therefore, the first sector is a typical "net benefit sector." The second sector not only issues relationships with other sectors, but also accepts relationships from other sectors. Most of the provinces in this sector are situated at the central region, at the center of the geographical location of the Yangtze River Economic Belt, and act as a “bridge” in the overflow path of the logistics relationship. "And the role of "intermediary", this sector is the "broker sector." The third sector has a spillover effect on both inside and outside the sector. The development of this sector’s logistics has not only met the needs of the sector’s regional market, but also has a spillover effect on the logistics market outside the sector. Therefore, the third sector is a “two-way spillover sector”. ". The members in the fourth sector mainly overflow the elements of logistics development for other sector members, and this sector is the "net overflow sector".

TABLE IV. Density matrix and image matrix

Sector	Density matrix				Image matrix			
	The first sector	Second sector	The third sector	Fourth sector	The first sector	Second sector	The third sector	Fourth sector
The first sector	1.000	0.000	0.000	0.000	1	0	0	0
Second sector	0.917	0.500	0.000	0.000	1	1	0	0
The third sector	0.625	0.167	0.500	0.750	1	0	1	1
Fourth sector	0.375	0.000	0.500	0.000	1	0	1	0

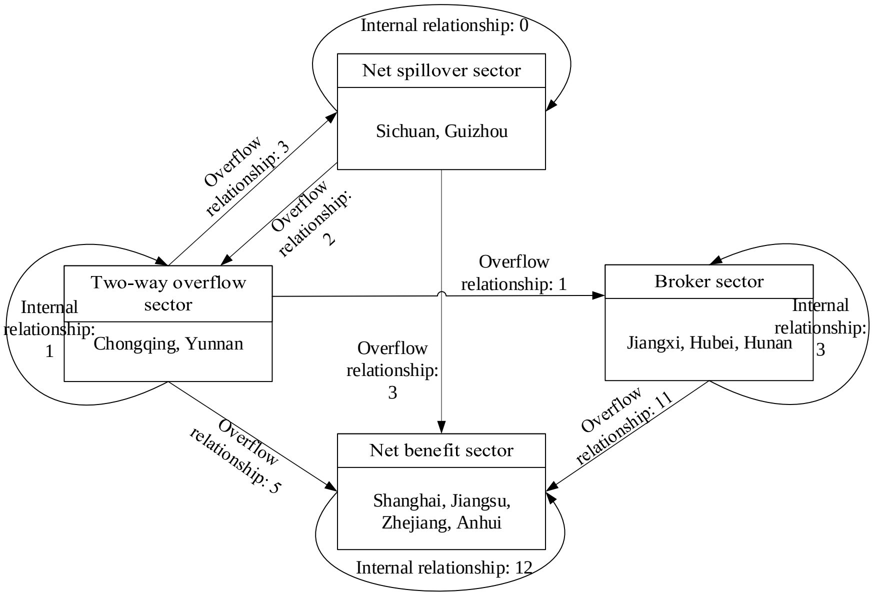

Fig 4: The relationship between the four major sectors of the logistics industry in the Yangtze River Economic Belt in 2017

In a bid to more intuitively show the distribution of relationships among the four major sectors, the network density matrix and the image matrix (see TABLE IV) are calculated with the help of Ucinet16.0 software, and the correlation diagram of the four major sectors is drawn (see Fig 4). Show) to examine the relationship and overflow path between the logistics sectors. It can be known from Fig 2 that the network density associated with the logistics spatial correlation of the Yangtze River Economic Belt in 2017 is 0.373. If the sector density is greater than 0.373, it indicates that the sector density is greater than the overall average level and has a tendency to concentrate in the sector. The value greater than or equal to 0.373 in the logistics density matrix is assigned to 1, and the value less than 0.373 is assigned to 0. In this way, the multi-valued density matrix of the logistics plate is transformed into an image matrix. From the analysis in Fig 4, it can be seen that the first, second, and third sectors have a relationship with regional logistics development within the sectors. At the same time, the first sector also benefits from the spillover effects of the second, third, and fourth sectors, demonstrating that the Yangtze River Economic Belt during the period of rapid logistics development, downstream areas need to provide plenty of corresponding logistics development resources from other provinces and cities, which is the final link of the power transmission path of logistics development. While the second sector accepts the spillover effect of the third sector, it mainly produces a spillover effect on the first sector. The fourth sector mainly played a spillover effect on the first and third sectors. In addition, while the third sector has a spillover effect on the development of logistics within the sector, it also exerts a spillover effect on the first, second and fourth sectors, which also shows that the logistics sectors are closely connected and the

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linkage effect between sectors is obvious.

3.2 Analysis of the Structural Effects of the Logistics Spatial Correlation Network

The location of the provinces and cities in the Yangtze River Economic Belt in the regional logistics network determines the difficulty of obtaining logistics development resources, and further affects the current logistics quality and level. Therefore, based on the analysis of the characteristics of the logistics spatial correlation network, the analysis of the effects of logistics quality and its inter-provincial differences from the characteristics of the individual network of logistics in the Yangtze River Economic Belt.

3.2.1 Indicator Description and Model Construction

Relative degree centrality, relative closeness centrality and relative intermediate centrality can well describe the "location advantages and disadvantages" of the provinces and cities in the Yangtze River Economic Belt. Therefore, this research takes the logistics quality of each province and city during the sample investigation period as the explained variable, and uses the three centrality of each province and city as the core explanatory variable to construct a panel data model for regression analysis. However, “location advantage” is not the only limiting factor for the improvement of logistics quality. Control variables such as fixed asset investment in the logistics industry, degree of opening to the outside world, government intervention, human capital, and technological level together constitute the driving mechanism for logistics development. . In summary, this paper constructs the following three models to explore the driving mechanism of logistics quality improvement and the structural effects of logistics spatial correlation network.

$$\text{Model 1: } \ln M_{it} = \ln deg_{it} + \ln invest_{it} + \ln open_{it} + \ln policy_{it} + \ln labor_{it} + \ln tech_{it} + \varepsilon_{it} \quad (3)$$

$$\text{Model 2: } \ln M_{it} = \ln clos_{it} + \ln invest_{it} + \ln open_{it} + \ln policy_{it} + \ln labor_{it} + \ln tech_{it} + \varepsilon_{it} \quad (4)$$

$$\text{Model 3: } \ln M_{it} = \ln betw_{it} + \ln invest_{it} + \ln open_{it} + \ln policy_{it} + \ln labor_{it} + \ln tech_{it} + \varepsilon_{it} \quad (5)$$

Where, M_{it} represents the logistics quality of province *i* in year *t*; deg_{it} represents the relative degree centrality of province *i* in year *t*; $clos_{it}$represents the relative proximity centrality of province *i* in year *t*; $betw_{it}$represents the relative intermediary center of province *i* in year *t*degree; $\text{invest}_{\text{it}}$ represents the fixed asset investment level of the logistics industry in province *i* in year *t*, expressed by the total fixed asset investment in transportation, warehousing and postal industries of each province and city as a percentage of regional GDP; $open_{it}$represents the level of openness in province *i* in year *t*, it is expressed as the proportion of total import and export trade in GDP; $policy_{it}$ expresses the degree of government intervention in provinces and municipalities *i* in year *t*, and it is expressed the proportion of transportation expenditures in total expenditures in the fiscal expenditures of provinces and cities; $labor_{it}$ expresses the manpower of provinces and cities in *i* in year *t*capital is expressed by the level of education of employees [31]; $tech_{it}$ is the technological level of *i* provinces and cities in *t* years, expressed by the amount of patents granted; $\varepsilon_{it}$is other unforeseen factors.

3.2.2 Analysis of Network Structure Effects

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The regression results of network centrality and local logistics quality are shown in TABLE V. Hausman test found that the test results of model one and model two support fixed effects, and model three support random effects. Among them, relative degree centrality, relative proximity centrality, and relative intermediary centrality passed the significance level tests of 1%, 5%, and 10%, respectively, showing that the individual network structure of the logistics industry has a vitaleffect on the quality of inter-provincial logistics. The coefficients of the three centrality indexes are all positive, indicating that the improvement of the centrality of the logistics spatial correlation network of various provinces and cities is conducive to the improvement of regional logistics quality.

TABLE V. Analysis results of network structure effects

	Model 1	**Model 2**	**Model 3**
Constant	-1.269*** (-2.96)	-2.904*** (-2.95)	-2.098*** (-4.51)
lndeg	0.189*** (2.68)	—	—
lnclos	—	0.555** (2.57)	—
lnbetw	—	—	0.044* (1.88)
lninvest	0.124*** (2.66)	0.125*** (2.68)	-0.198** (-2.38)
lnopen	0.078* (1.97)	0.085** (2.16)	0.133** (2.10)
lnpolicy	0.047 (1.65)	0.052* (1.83)	-0.121** (-2.25)
lnlabor	-0.431 ** (-3.78)	-0.426*** (-3.73)	-0.132 (-0.83)
lntech	0.043*** (1.83)	0.041* (1.73)	0.120*** (2.87)
Hausman	57.88***	86.06***	234.82
FE/FE	FE	FE	RE
F	4.73***	4.62***	—
Wald value	—	—	47.20***
R^2	0.214	0.210	0.792

Note: *, **, and *** indicate the effect is significant at the levels of 10%, 5%, and 1% respectively. The values in parentheses are t statistic or Z statistic of the coefficient.

The consequences of Model 1 in TABLE V show that the improvement of relative degree centrality is beneficial to the improvement of logistics quality in various provinces and cities. The regression coefficient of relative degree centrality is 0.189, and it is essential at the level of 1%, showing that for every 1 percentage point increase in the relative degree centrality of the

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Yangtze River Economic Belt, the logistics quality of the Yangtze River Economic Belt will increase by 0.189 percentage points, which means that the more provinces and cities are in the center of the logistics related network, the higher the degree of logistics spatial correlation with other provinces and cities, the more they can benefit from the development process of the logistics of the Yangtze River Economic Belt. For example, Hunan, Sichuan, Guizhou, and Yunnan, which rank the bottom four in terms of relative degree centrality, have relatively few local logistics spatial correlations in the logistics spatial correlation network. Hunan and Sichuan can enhance their logistics spillover effects on surrounding provinces and cities. The spatial relevance of logistics, and Yunnan and Guizhou can make up for their geographical disadvantages and improve their own logistics quality by strengthening trade, talent, industry, information, and technology exchanges with neighboring provinces and cities.

The results of Model 2 show that the regression result of relatively close to centrality is 0.555, and it is crucial at the 5% level, showing that the relative closeness to centrality of the provinces and cities has a positive effect on logistics quality. This means that as the relative proximity to the centrality increases, provinces and cities are brought closer to the central provinces and cities in the logistics spatial correlation network, and the logistics spatial correlation differences between provinces and cities are reduced. At the same time, the "economic distance" between provinces and cities, the gradual shortening of the relationship between provinces and cities has become closer, and the degree of cross-regional logistics cooperation is higher. The improvement of inter-regional logistics relevance promotes the realization of the "cost reduction" effect of logistics resource flow. For example, provinces with relatively low centrality, such as Hunan, Sichuan, Guizhou, Yunnan, etc., can strengthen the relationship with the network center provinces and cities through exchanges and cooperation in industry, information, and trade, and reduce logistics costs. Quality improvement creates good conditions.

The results of Model 3 show that in the logistics spatial correlation network, the increase in the relative intermediary centrality of the provinces and cities will drive the improvement of the logistics quality of the Yangtze River Economic Belt. This means that the more the provinces and cities are in the "intermediary" position of the logistics spatial correlation, the more they can make full use of the superiority of the "bridge", effectively guide the flow of logistics resources to produce spillover effects and benefit from it, and ultimately achieve a "win-win" situation. For example, provinces such as Anhui, Jiangxi, Hunan, Sichuan, and Guizhou, which have relatively low intermediary centrality, play a "bridge" regulatory role through provinces and cities with relatively high intermediary centrality to enhance the spatial relationship with other provinces and cities, and reduce the spatial difference of logistics quality between provinces and cities can achieve continuous improvement of logistics quality. It can be known that the status of the provinces and cities in the network is an important factor affecting their own logistics quality. Therefore, improving its position in the network, shortening the gap with other provinces and cities, and enhancing the allocation of logistics resources are the keys to the

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steady improvement of logistics quality and development in the provinces and cities and their regions.

IV. CONCLUSION

This paper uses social network analysis to deconstruct the spatial relevance of regional logistics based on the data of provinces and cities in the Yangtze River Economic Belt from 2007 to 2017. First, the improved gravity model is used for confirming the logistics spatial correlation network relationship, and on this basis, the features of the logistics spatial correlation network structureare analyzed; secondly, the spatial correlation generated by the individual logistics network characteristics of each province and city Empirical research on network structure effects. The research conclusions are summarized as follows:

(1) From the point of the overall network structure characteristics, during the sample inspection period, the degree of spatial closeness of logistics in the Yangtze River Economic Belt has gradually increased, but the cooperation between regions still needs to be strengthened. The changes in network density and the number of network correlations indicate that the logistics links between provinces and cities in the Yangtze River Economic Belt are complex and close, and there is a lot of room for improvement, which can further strengthen regional cooperation. The changes in network relevance and network hierarchies show that there are universal spatial relevance and spatial spillover effects between provinces and cities. The overall network efficiency is declining, and the stability of the network is gradually improving.

(2) Observing the characteristics of individual network structure, the status and role of various provinces and cities in the regional logistics network are different. Shanghai, Jiangsu, Zhejiang, Hubei, and Chongqing are at the center of the network. They act as the central actor in the logistics spatial correlation network. They can quickly connect with other provinces and cities and have a strong ability to obtain resources. Hunan, Sichuan, Guizhou, Yunnan and other provinces have relatively low relative degree centrality, relative proximity centrality, and relative intermediary centrality. They have few direct connections with other provinces and cities, and are at the edge of the network. Among them, due to local network differences, the core provinces and cities of Hubei and Chongqing have weakened the status of some neighboring provinces such as Hunan and Sichuan.

(3) From the point of spatial agglomeration characteristics, the Yangtze River Economic Belt can be separated into four different functional sectors. The first sector is the "net benefit sector" composed of Shanghai, Jiangsu, Zhejiang, and Anhui situated in the lower reaches of the Yangtze River, this sector mainly receives spillover effects within and between sectors. The second sector is concentrated in Jiangxi and Hubei in the middle reaches of the Yangtze River the “broker sector” composed of three provinces in Hunan. This sector not only accepts spillovers from other sectors, but also sends out spillover relationships to other sectors. The third sector is the “two-way spillover sector” composed of Chongqing and Yunnan, which covers both domestic and overseas markets, there are spillover effects to the outside world. The

fourth sector is the "net spillover sector" composed of Sichuan and Guizhou, which mainly produces spillover effects to other sectors.

(4) From the results of the analysis of spatial correlation network structure effects, the spatial correlation network structure of logistics has a significant impact on the quality of logistics. The improvement of individual network centrality can significantly improve logistics quality and reduce regional differences in logistics. The relative degree centrality, relative proximity centrality, and relative degree centrality of the network have a positive impact on logistics quality.

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