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Research on the Network of Scientific and Technological Innovation and Its Influencing factors in Yangtze River Delta Urban Agglomeration

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ABSTRACT: *The Yangtze River Delta is one of China's most powerful city clustersand its scientific and technological innovation capability also ranks in the forefront. In the era of digital economy, the ability of scientific and technological innovation is an important factor to evaluate the development potential of a region, and the degree of integration of scientific and technological innovation in urban agglomerations is of great significance to the coordinated development among cities. Therefore, this paper analyzes the spatial correlation characteristics of scientific and technological innovation in Yangtze River Delta urban agglomeration, and finds out the main factors affecting the correlation degree. The research finds that the overall level of scientific and technological innovation correlation in the Yangtze River Delta city cluster is relatively high, and it is mainly radiate from the core cities of Shanghai, Suzhou, Hangzhou and Nanjing. The correlation of scientific and technological innovation is mainly affected by four factors: policy, geographical location, city scale and economic strength.*

KEY WORDS: *Urban Agglomeration of Yangtze River Delta, Science and technology innovation correlation,Social network analysis*

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I. INTRODUCTION AND LITERATURE REVIEW

In 2016, the National Development and Reform Commission of China issued the *Yangtze River Delta City Cluster Development Plan*, which proposed that Yangtze River Delta city clusters includes 26 cities in Shanghai, Zhejiang, Jiangsu and Anhui provinces.And in 2019, the Communist Party of China Central Committee and the State Council jointly issued the *Outline of the Regional Integration Development Plan of the Yangtze River Delta*, calling for the integrated development of the Yangtze River Delta. As one of China's most economically active, open and innovative regions, Yangtze river delta's economy accounts for about 23.6% of the country, with 8 "Double First-Class" university, which accounts for 20% of the country, and 74 national key laboratories. What's more, it's research input equivalent to one-third of the national total and patent applications accounted for 32.4%. Yangtze River Delta has become the source of national technological innovation. Although the overall level of innovation is high, there are significant differences in the technological innovation ability among cities.The number of patents granted in 2018 was 92,460 in Shanghai and 55,379 in Hangzhou, but only 2,216 in Zhoushan and 1,567 in Tongling. The huge difference in the level of scientific and technological innovation has become a serious obstacle to the comprehensive and coordinated development of innovation.In the era of digital economy, breakthroughs in scientific and technological innovation require not only every single effort, but also coordination with other regions. Therefore, the Yangtze River Delta region also needs to cooperate closely with other cities to jointly promote the integrated development of scientific and technological innovation.

At present, many scholars have studied the spatial correlation of scientific and technological innovation. By calculating Gini coefficient and Moran coefficient, Zhang and Li (2007) verified that there was obvious spatial dependence and spatial correlation between innovation outputs of provinces in China. Jin et al. (2018) found that the level of China's regional innovation network is in a pattern of high in the east and low in the west, and the eastern region is mostly at the core of the spatial correlation network, which forms an obvious innovation linkage effect by absorbing innovation resources in the central and western regions. Geographical location, economic base and investment of innovation resources are the main factors that affect the spillover of innovation cyberspace. Liu and Feng (2019) used the network analysis and QAP method to analyze the characteristic indexes of regional innovation space association, and concluded that there was high regional innovation association and robustness, but low tightness, and spillover has threshold effect.Lv et al. (2019) found that China's regional scientific and technological innovation in the spatial correlation characteristics and spatial correlation network has good robustness. Chinese regional scientific and technological innovation can be divided into four functional plate, and there are obvious spatial spillover gradient features among plates.Geographical proximity, economic development gap and differences in the degree of opening to the outside world are positively promoting the spatial relevance of regional scientific and technological innovation.

Existing literatures revealed that scientific and technological innovation among regions has spatial overflow characteristics and spatial correlation characteristics to a certain extent, and some research discussed corresponding influencing factors, but there are still two deficiencies: In the one hand , most studies analyze the overall spatial pattern of regional Sci-Tech innovation, but neglect the inter-city correlation network.On the other hand, there are many studies focus on scientific and technological innovation across the country, emphasizing the differences between the east and the west. But few studies on specific regions, such as city cluster. and there may be differences in influencing factors.Therefore, this paper will measure the correlation degree of Sci-Tech innovation network in Yangtze River Delta urban agglomeration by revised gravity model and social network analysis method. And then we will discuss the factors that are influence the network and put forward some suggestions to promote theintegrated development of Sci-Tech innovation in the Yangtze River Delta and other city clusters.

II. RESEARCH METHODS AND RESEARCH OBJECTIVES

2.1 Research Methods

2.1.1 Gravity model

The gravitation model is based on Newton's universal gravitation formula and is often used to analyze the spatial relationship between two cities.Tinbergen (1962) and Poyhonen(1963) developed and extended it in the field of economics and proposed a relatively complete and simple economic model.After continuous expansion, it has been regarded as a bridge connecting physics, social sciences and economics that used in many research fields such as spatial layout, tourism and trade.On the basis of the original gravity model, combined with the research purpose of this paper, we construct the following expression for the gravity model:

$$R_{ab} = k_{ab} \frac{M_a M_b}{D_{ab}{}^2}$$

R_{ab} represents the radiation effect of city A on city B, M_a and M_b represent the "quality" of city A and City B respectively, D_{ab} represents the distance between the two cities, k_{ab} is the correction coefficient, which is generally set artificially. In this paper, we set

$$k_{ab} = \frac{M_a}{M_a + M_b}$$

$$k_{ba} = \frac{M_b}{M_a + M_b}$$

k_{ab} and k_{ba}respectively represent the influence coefficient of city A to city B and city B to city A.

2.1.2 Social network analysis

As a social science research theory developed from social measurement method, Social Network Analysis (SNA) is mainly used to study social structure and social relations. In addition, it is widely used in resource allocation, enterprise network, urban spatial structure analysis and other fields. The main indexes of SNA include network density, centrality, agglomerate subgroup and block model.

Network density is one of the commonly used indexes of social network analysis, which represents the closeness of member in the social network. The closeness degree is measured by the ratio of the actual number of relational edges to the number of theoretical edges. In a directed relational network, the density can be expressed as:

$$D = \frac{L}{n(n-1)}$$

D is the network density valued in 0 and 1. L is the number of relationships that actually exist; n is the number of nodes in the network. The higher the network density is, the closer the internal connection of the network is.

Centrality is an index to study the position and function of each region in the network, which include centrality degree and centrality potential.Centrality is a quantitative index reflecting the magnitude of centrality. The most studied indexes are point centrality and betweenness centrality.The point degree centrality of a node is the number of other points directly connected to the point. If a point is directly connected to many other points, the point has a high point degree centrality. In a network of size n, the point degree centrality of node I can be expressed as:

$$C_D(i)=\sum_{j=1}^{n} x_{ij} \qquad (i \neq j)$$

However, the larger network size often has higher point degree centrality. In order to eliminate the influence of network size, relative point degree centrality is proposed, which can be expressed as follows:

$$C_{RD}(i)=\frac{C_D(i)}{n-1} \qquad (i \neq j)$$

Betweenness centrality measures the control ability of a point in the network. In the network, if a node is on the path of many other points, that is, it acts as a bridge between the other two nodes, it can be considered as having an important position and has a strong control ability over resources.
Cohesive subgroups are used to reveal and characterize the states of the internal substructures of a network. The nodes with strong, direct, close or frequent connections are divided into a subgroup and then analyze the connections within each subgroup and among subgroups.

2.2 Research Objectivesand Data Sources

There are many indicators to measure the scientific and technological innovation ability of a city, such as the number of patent applications, patent authorization, investment in scientific research, high-tech output value, high-tech enterprises, etc. However, the number of patents granted is a direct reflection of the city's innovation ability. Therefore, this paper selects the patent authorization volume of 26 cities in the Yangtze River Delta in 2018 as the index to measure the city's scientific and technological innovation ability. The data is from the statistical yearbook and the distance between cities is from the Google map.

III. SCIE-TECH INNOVATION NETWORK

The gravity value of scientific and technological innovation between two cities in the Yangtze River Delta is calculated according to the gravity model, and the incidence matrix of scientific and technological innovation is constructed.Then we import matrix into UCINET software for binarization processing, which result is related to the threshold value. In this paper, according to the actual situation, we set that if the gravity value is bigger than 400, it is set as 1, which means these two cities have a certain relationship in scientific and technological innovation, while the others are 0.And then we get theYangtze River Delta scientific and technological innovation network as shown in Figure 1 below by UCINET visualization.In addition, density, network centrality and cohesive subgroups can also be calculated by UCINET.

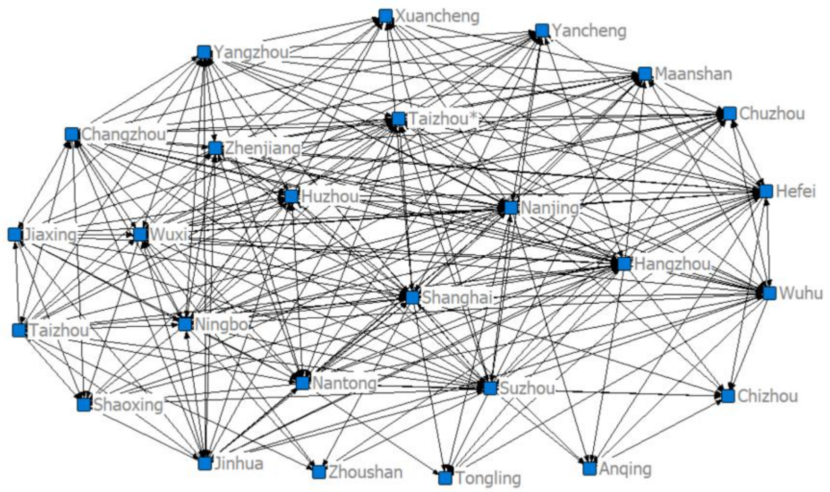

Figure 1:Sci-Tech innovation Network in The Yangtze River Delta city cluster
Note:Taizhou in Zhejiang province, Taizhou in Jiangsu province, the same below*

Figure 1 shows that there is a certain connection among cities in the Yangtze River Delta in terms of scientific and technological innovation. Shanghai, Nanjing, Suzhou, Hangzhou, Hefei and other cities with complex and close connections are the core node of the network and radiate outwards. While Zhoushan, Tongling, Anqing, Chizhou, Taizhou and other cities are on the edge of the city, which is not closely connected with other cities.

3.1 Network Density Analysis

According to the calculation, there are 371 actual connections in the Yangtze River Delta, with a density value of 0.571.It shows that the overall connection density of the Yangtze River Delta is relatively high, but there is still a large space for rise. In order to reveal the overall development and evolution of Sci-Tech innovation networks, the paper calculates the network density and connections in 2005, 2010 and 2015 respectively(Figure 2).

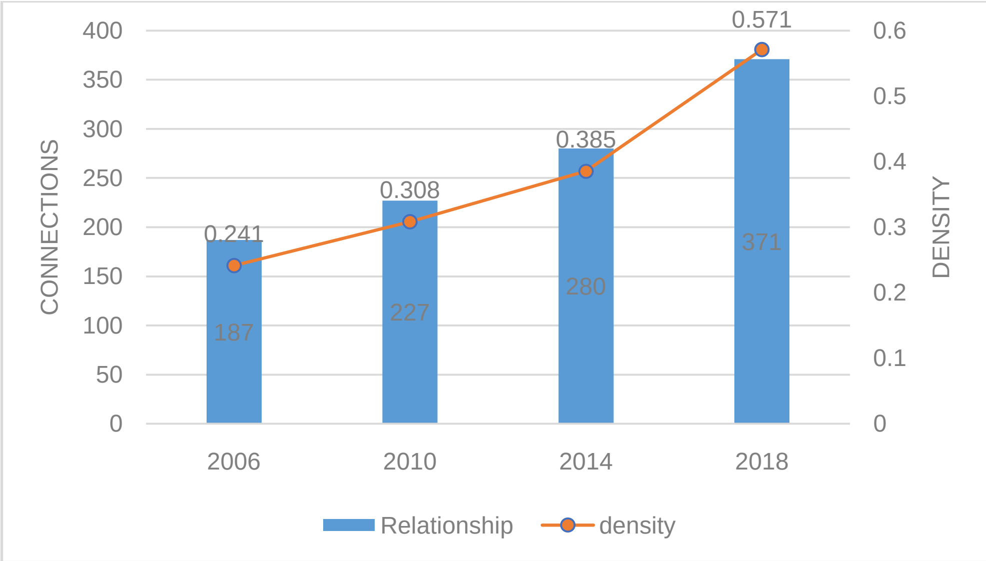

Figure 2: Network Density and Connectionsin Different Years

The Figure 2 shows that the density and connections in the Yangtze River Delta are increasing year by year, which indicates that the degree of scientific and technological innovation among cities is getting closer and closer.It can be predicted that with the development of digital technology and policy of promoting scientific and technological innovation and Yangtze River Delta integration, the degree of scientific and technological innovation in the Yangtze River Delta region will continue to increase in the future.

3.2 Centrality Analysis

UCINET is used to calculate the degree centrality, closeness centrality and betweenness centrality of the network. Since the innovation network is a directed network, the in-degree and out-degree are further distinguished to measure the degree ofinfluence and be influenced(Table Ⅰ).

Table Ⅰ:Degree of Sci-Tech Innovation Centrality in Yangtze River Delta

	degree centrality		**closeness centrality**		**betweenness centrality**
	In	Out	In	Out	
Shanghai	17	25	19.38	96.15	14.30
Suzhou	17	25	19.27	96.15	14.30
Hangzhou	18	25	19.53	96.15	38.30
Nanjing	18	24	19.23	96.15	19.77
Nantong	17	22	19.52	83.33	8.45
Wuxi	17	22	19.32	86.21	8.38
Ningbo	15	22	18.94	86.21	5.43
Hefei	16	21	19.23	83.33	12.59
Changzhou	18	21	19.63	83.33	8.49
Huzhou	17	21	19.38	83.33	5.46
Zhenjiang	18	20	19.78	80.65	9.93
Yangzhou	18	19	19.54	78.13	8.41
Wuhu	16	18	19.67	75.76	30.46
Taizhou*	16	17	19.37	75.76	1.76

Jinhua	13	17	18.66	73.53	0.69
Taizhou	11	16	18.33	69.44	1.27
Yancheng	13	11	18.66	60.98	0.00
Jiaxing	14	9	18.80	54.35	0.27
Maanshan	15	8	19.08	54.35	0.75
Chuzhou	15	5	19.26	52.08	0.00
Xuancheng	13	1	18.66	43.86	0.00
Anqing	6	1	21.55	4.00	0.00
Shaoxing	12	1	18.52	51.02	0.00
Chizhou	8	0	27.78	3.85	0.00
Tongling	7	0	21.74	3.85	0.00
Zhoushan	6	0	21.01	3.85	0.00

In general, the overall degree of connection in urban agglomeration is relatively high, but the centrality in different cities is quite different.In terms of degree centrality, Shanghai, Suzhou, Hangzhou and Nanjing have high in-degree and out-degree, indicating that these cities have close relationship with other cities. In particular, Shanghai, Suzhou and Hangzhou are connected with all the cities, indicating that these three cities are at the core of the Yangtze River Delta city cluster, with strong radiation capacity and great influence on the scientific and technological innovation of other cities. From the view ofout-degree, Changzhou, Zhenjiang and Yangzhou are also at a higher level, which means that these cities are good at absorbing external resources and in a position to benefit from the network. However, cities such as Xuancheng, Anqing, Chizhou and Tongling have low value in both aspects.It means that they are less influenced by other cities and have limited influence on technological innovation in other cities.

From the perspective of the betweennesscentrality, Hangzhou and Wuhu are far higher than other cities. Shanghai, Suzhou, Nanjing and Hefei also have a prominent centrality, indicating that these cities play an important role in controlling the flow of resources between cities. They act as Bridges and intermediaries and can directly influence the development of the whole network. However, the betweenness centrality in Anqing, Xuancheng, Chizhou, Zhoushan and other small cities is 0, which has almost no influence on the connectivity of the network.

Hangzhou and Wuhu are far higher than other cities, indicating that these two cities play a greater role in controlling the flow of resources among cities and play an important role in the network. For various reasons, cities such as Anqing, Xuancheng, Chizhou and Zhoushan do not act as Bridges or intermediaries in the network, and have little influence on the network.

The closeness centralityexpresses the integration ability of a city. The higher its value is, the easier it is for other points to get to. The out-Closeness represents the radiation ability of the urban node. The higher the value is, the easier it is to get to other points. From this point of view, Chizhou, Anqing, Tongling, Zhoushan ect. have a high degree of input and a low degree of output, which shows that they are not the core nodes in the network and are easily controlled and influenced by other cities while have little or no influence on other cities. Shanghai, Suzhou, Hangzhou and Nanjing have a high out-Closeness, indicating that these cities have a greater impact on other cities and are at the core of the urban agglomeration network.

3.3 Cohesive SubgroupAnalysis

CONCOR method in UCINET was used to analyze condensed subgroups.The 26 cities of the Yangtze River Delta are divided into 4 subgroups as shown in Figure 3. The first group includes Shanghai, Changzhou, Nantong, Yancheng, Suzhou and Wuxi. Second category includes Jiaxing, Jinhua, Zhoushan, Taizhou, Hangzhou, Huzhou, Ningbo, Shaoxing; Category 3 is Hefei, Zhenjiang, Nanjing, Yangzhou, Chuzhou and Taizhou; The last group includes Wuhu, Chizhou, Xuancheng, Tongling, Anqing, Maanshan.

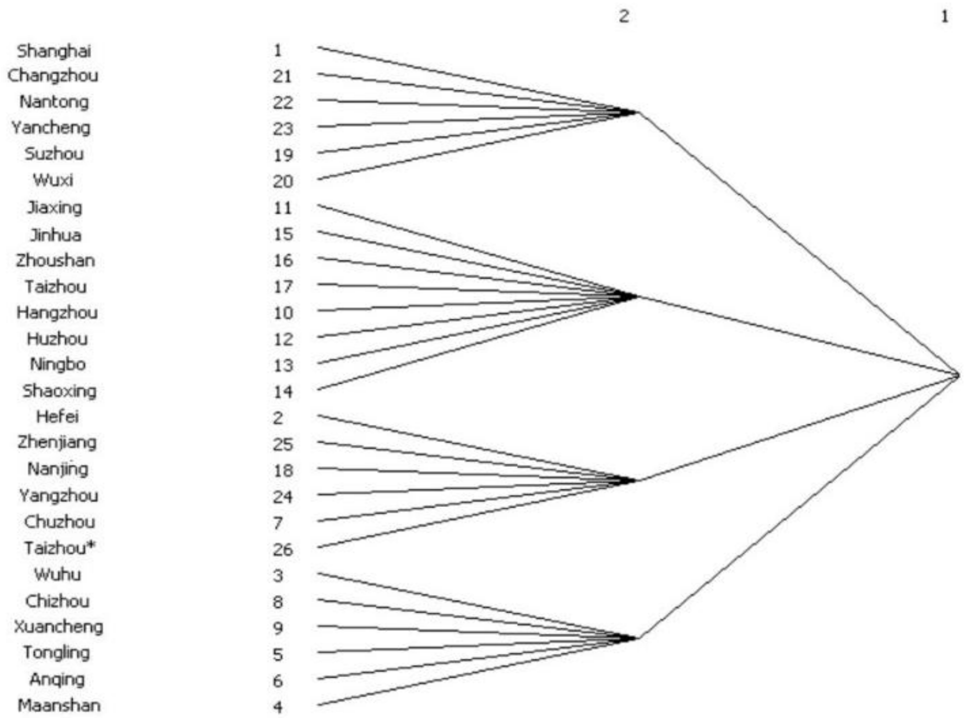

Figure 3: Sci-Tech Innovation Network Cohesive Subgroup

IV. INFLUENCING FACTORS AND SUGGESTIONS

4.1 Influencing Factors

On account of the comprehensive analysis of all the indexes calculated above, it can be found that the degree of correlation among cities in scientific and technological innovation is affected by various factors. Here are the mainly four factors:

(1) Policy factors. As can be seen from the density and connection numbers in Figure 2, the density of Sci-Tech innovation network in the Yangtze River Delta is gradually increasing, especially in recent years, and the growth rate is obviously increased. A series of development plans for the Yangtze River Delta issued by the state have played an important role, providing solid policy support for Sci-Tech innovation Communication among cities in the Yangtze River Delta.

(2) Geographical location. From the classification of cohesive subgroups, it can be seen that the classification of each subgroup has obvious differences in administrative divisions and geographical location. Those in same province or close in location are often grouped in the same subgroup, which indicates that regional factors play a greater role in the association of Sci-Tech innovation.

(3) City scale. By comprehensively analyzing the overall correlation density andeach subgroup density, it can be found that though the overall density is relatively high, it mainly relies on the interaction between several core large cities, while the small cities are less connected and lack of inter-city communication, failed to participate in the integration of Sci-Tech innovation in the Yangtze River Delta.

(4) Economic strength. From the perspective of centrality, Shanghai, Hangzhou, Suzhou, Nanjing and other economically developed cities have a higher level and are in the core position. While Tongling, Anqing, Chizhou and other less developed cities are lower in value and in the edge of the network. It shows that the economic development of cities, to some extent, also has influence on the correlation of scientific and technological innovation.

4.2 Suggestions

For the above analysis, this paper puts forward the following four Suggestions to promote the integrated development of Sci-Tech innovation in the Yangtze River Delta and provide reference for other regional integration development.

(1) Continue to strengthen policy support. In the context of integration of Yangtze river delta development, local governments should pay enough attention to optimize the technology innovation policy and environment. On the one hand, it will attract more talents and investment into the region to improves local Sci-Tech innovation ability. On the other hand,it provides opportunities for innovation communications and cooperation among cities so that the talent and capital can flow freely.

(2) Break administrative divisions and regional barriers with the help of transportation integration and information technology.In order to minimize the gap caused by administrative divisions and distance, cities should make full use of transportation integration and advanced information technology to strengthen innovation communications among provinces and cities. The first step is reinforcing transportation infrastructure and optimizing transportation services. And the next step is ICT infrastructure construction, promoting the openness and sharing of Sci-Tech innovation information.

(3) Attach importance to the improvement of the correlation degree of small cities. The government should provide more opportunities and facilities for technological innovation in small cities so that they can establish links with core cities.The most important thing is to prompt the small cities into the network and then improve the in-degree, so that the influence and radiation of big cities can drive the innovation and development of small cities.

(4) Continue to promote economic development and increase investment in scientific research.Powerful economic forces provide a solid material foundation for Sci-Tech innovation. The government should increase the investment in scientific research, especially the special allocation for cities with weak economic strength.

V. CONCLUSIONS

Based on gravity model and social network analysis, this paper measures the degree of correlation of scientific and technological innovation among cities in the Yangtze River Delta urban agglomeration.UCINET software was used to calculate the network density, centrality and divide cohesion subgroups. The results show that the overall level of scientific and technological innovation correlation was relatively high, but the degree of internal connection was quite different.Shanghai, Suzhou, Hangzhou and Nanjing are the core cities to driving the innovation and development of the Yangtze River Delta.However, Chizhou, Xuancheng, Tongling and other small cities in Anhui have not fully participated in the network, so that their innovative connections with other cities need to be further deepened.Further analysis on the spatial correlation and urban characteristics reveals that the main factors affecting the correlation are policy factors, geographical location, city scale and economic strength.Policy plays an important role in the overall linkage of scientific and technological innovation in the Yangtze River Delta. The closer the geographical location, the larger the city scale and the stronger the economic strength, the stronger the connection among the cities.Based on the above analysis, four Suggestions are put forward to provide reference for the coordinated development of scientific and technological innovation in Yangtze River Delta and other regions, which includes strengthening policy support, making full use of convenient transportation and information technology, attaching importance to the correlation degree of small cities and continuously promote economic construction.

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