Research on Scientific and Technological Cooperation Network of Cities in Pan-Yangtze River Delta of China：Based on Social Network Analysis*

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Abstract

The cultivation and construction of scientific and technological cooperation between cities play an important role in strengthening the regional technology innovation and competitiveness. Based on the perspective of cooperation network, this paper studied the scientific and technological cooperation network of cities in Pan-Yangtze River Delta by the method of SNA (Social Network Analysis). We found that the density and intermediary were the key factors which affected the function of the network. Then some policy suggestions in construction of scientific and technological cooperation network of cities were given, finally the promotion ways of scientific and technological cooperation between cities were proposed.

Keywords: Social Network Analysis; Cooperation Network; Pan-Yangtze River Delta; Mediating Effect

1. Introduction

Pan-Yangtze River Delta is the largest urban agglomeration and the most well developed region in China. With the upgrading of traditional industries and the rapid growth of high-tech industries, the development of cities in Pan-Yangtze River Delta depend more and more on science and technology (S.&T.) (Lin, 2010). With the development of the Yangtze River Delta regional integration, the establishment of regional synergistic interaction mechanism to develop scientific and technological cooperation and technology transfer activities became more and more urgent (Liu, 2009). The development level of the cities in Pan-Yangtze River Delta is significant different, so does the development of the S.&T. The cooperation between cities in one area will optimize the allocation of resources within the region, strengthen innovation ability and competitiveness of cities, change the mode of economic growth and achieves better and faster development to the cities.

The cities in Pan-Yangtze River Delta area have good tradition of S.&T. cooperation, and already formed a tightly cooperation network. Optimization of cooperation network characteristics can significantly improve the quality and quantity of the cooperation between cities (Feng et al., 2011). Many scholars studied the partnership between cross-regional cities from the perspective of cooperation network, but few study it in one region (Feng et al., 2009). The purpose of this research is to study the S.&T. cooperation network of cities in Pan-Yangtze River Delta area from cooperative network perspective, build the network map and identify the problems by analyzing the characteristics of the map. Then some policy suggestions to improve the S.&T. cooperation network of cities were proposed.

Network is one of the most important carriers of S.&T. cooperation between cities. By studying the relationship of S.&T. cooperation between cities from the perspective of SNA (Social Network Analysis), we can find its characteristics and existing problems more clearly.

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At present, scientific and technological cooperation network of cities in Pan-Yangtze River Delta is not mature and in the stage of construction. Thus this paper began with the analysis of the present situation, and then the problems, finally the improvement suggestions.

2. Methods

2.1 The route of the methods

SNA has been used since 70 years before. Through constant development, it has become a clear set of specific area or research method. The main application area is no longer restricted in the traditional small group relations, but extends to include from the social lives to political and economic activities, and also the interpersonal relationships to all aspects of the world system (MEJ, 2001). The introduction of computer technology makes the large and complex networks simplified and structured easily. Some of the social network analysis software, such as Ucinet and NetDraw, enable the visualization of social network, and allow people to process and analysis a large number of abstract data (Zhao & Wang, 2011).

The frame of the methods in this paper is using the network model to describe the structure of S.&T. cooperation of cities in Pan-Yangtze River Delta, which can be used to study the persistent pattern of S.&T. cooperation relationships in the cities. The method was formed as follow: firstly, selected the city nodes, and then found out the data of S.&T. cooperation of the cities in the method of network retrieval; secondly, in order to directly find the characteristics of the S.&T. cooperation network and use as the basis for further research, the cooperation relationship data was visualized with NetDraw, and forms the S.&T. cooperation network diagram of cities of Pan-Yangtze River Delta; thirdly, we used Ucinet to do the centrality analysis, intermediary analysis and cluster analysis; finally, the qualitative suggestions were given based on the problems we have found.

2.2 The S.&T. Cooperation Network Diagram

2.21 Selected of the City Nodes

Based on the city's list from “The Yangtze River Delta City Economic Coordination Meeting” and the urban economic development level of each city, we select 23 Pan-Yangtze River Delta cities: Hefei, Wuhu, Ma'anshan in Anhui province, Nanjing, Suzhou, Wuxi, Changzhou, Nantong, Yangzhou, Taizhou, Zhenjiang, Huaian ,Yancheng in Jiangsu Province, Hangzhou, Ningbo, Quzhou, Shaoxing, Jiaxing, Taizhou, Huzhou, Zhoushan, Jinhua in Zhejiang province, and city of Shanghai. The cities selected have a well relationship and tradition on city cooperation, and they are more active in the urban economy and technology innovation.

2.22. Measurement of Connection and Data Selection

The existence of S.&T. cooperation between cities has no statistics available for reference, to gather relevant information, we used the network retrieval method. In order to ensure the retrieval process comprehensive, complete and accurate, the data acquire from the following two ways:

Searched the cities in pairs on the internet, judged and selected the information obtained, and determine if there is S.&T. cooperation between the two cities. If the governments of the two cities have signed S.&T. cooperation agreements or framework, or there are research institutes or university located in one city signing framework or agreement with the other civic government, we believe that the two cities have a S.&T. cooperation relationship.

Through home pages of all cities' technology department, read through and judge the information of the columns such as the “technology cooperation or external cooperation”, and amend the data obtained before. The integrated use of the two means, covered the most likely source of the required data channels, and ensured the integrity of the information. As well, the cross-use of the two means can test the data with each other, and ensures the accuracy of the information. If two cities have a S.&T. cooperation relationship, we mark there relationship as 1. Or we mark in as 0. We search 253 times for 23 cities and find that 69 groups have established a S.&T. cooperation relationship and 184 groups have not.

2.23. Visualization of S.&T. Cooperation Network

We formed the relationship information above as binary data matrix, and draw the S.&T. cooperation network diagram of cities in Pan-Yangtze River Delta with the software of NetDraw, as in Figure1.

Insert Figure1 here

2.3 The Characteristics of S.&T. Cooperation Network

2.31. The Basic Characteristics

In the social network, Network Size means the number of the actors. Network Size is the important variable that reflects the complexity of the network. The Network Size of S.&T. Cooperation Network of Pan-Yangtze River Delta cities is 23.Node Degree refers to the number of lines that associated with the node, also known as Correlation. In the network diagram, we can see that Shanghai has the highest node degree, but Taizhou, Huaian and Yangzhou have the lowest node degree. The Average Node Degree can reflect the average correlation index of the network. It can be calculated as d=2L/N, where L indicates the number of lines and N is the number of nodes. The average node degree of the network is 6.

In SNA, Density refers to the proportion those real lines in the network of all possible lines. If there are N nodes in an undirected graph, and the actual number of connections is L, then the density can be calculated as $\Delta = 2L / N(N-1)$. And density reflects the degree of relationship of social networks. Based on the differences in the density, networks diagram can be divided into Whole Map, High-Density Map, Low-Density Map, and Non-Join Map. The Density of the network this paper mentioned is 0.273, and we claim that it belongs to the low-density map.

2.32 The Analysis of Centrality

Centrality is the measurement concept about the actors' location in the social networks, reflecting differences of the actors' structure or the advantages of the location in the social network (Freeman, 1979). Scholars generally classified it into the Node Centrality, the Closeness and the Betweenness (Chen, 2005). The Node Centrality of each city node determined the concentration of the city, and high Node Centrality means the city is in a more "center" position. Scholars generally use standardized methods to calculate the node centrality. The formula is as follows (Lin, 2008):

$$C_D^{'}(n_i) = d(n_i)/(N-1)$$

The Node Centrality of cities in Pan-Yangtze River Delta Area can be listed as shown in Table 1. The Node Centrality of Shanghai is the highest and it is the absolute center of the network. Hangzhou, Nanjing, Hefei have the relatively high node centrality, which are the sub-centers of the network.

Insert Table 1 here

The Closeness centrality can be used to determine the Closeness or distance between one actor and all other actors. High level of Closeness centrality indicates that the city is closely to the other cities. The Closeness centrality of one city can be measured by the degree of the distance between cities. And the distance can be measured by the geodesic. The formula is as below (Lin, 2008):

$$C_C = [\sum_{j=1}^{n} d(n_i, n_j)]^{-1}$$

The results are shown in table.2. We can found that Shanghai has the highest degree of tightness with rest cities, and Shanghai is followed by Hangzhou, Nanjing, and Hefei. Taizhou, Huaian, and Yangzhou have the lowest Closeness centrality.

Insert Table 2 here

The Betweenness can be used to measure the extent of one city to be the intermediary of other cities. Intermediary role is often played a role of a bridge or a role of control, so in a sense, it can measure the extent that one city can control the S.&T (Rowley, 1997) cooperation relationship of other cities.

If g_{jk} is the number of geodesics that existing between city j and city k, then the probability that all these short-lines are selected as the communication path is $1/g_{jk}$. If we make $g_{jk}(n_i)$ the number of geodesics of the two cities which are connected with city node n_i. And the Betweenness of n_i will be the sum of the probabilities of $g_{jk}(n_i)/g_{jk}$, as shown below (Lin Juren, 2008):

$$C_B = \sum_{j<k} g_{jk}(n_i) \Big/ g_{jk}$$

Then we can calculate the Betweenness of the city nodes. The results are shown in Table3.

Insert Table 3 here

As shown in the table, in the S.&T. cooperation network of Pan-yangtze River Delta Area, Shanghai, Hangzhou, Nanjing, Hefei and Suzhou have higher Betweenness level. That means these cities are intermediate nodes and play an important role in communication network.

And giving more policy support to these cities can help them to be full into playing their roles of intermediary and improve the S.&T. cooperation network.

2.4 The Similarity of the Cities in S.&T. Cooperation Network

According to the structure of the S.&T. cooperation network, this paper use Cluster method to analyze the similarity of the cities. Cluster method is based on the relevant methods, and the main principle is using the correlation coefficient to measure the degree of correlation between variables, which can show the degree of similarity between actors. This paper used the Pearson product-moment correlation coefficient, and the formula is:

$$r_{ij} = \frac{\sum_{k=1}^{n} (x_{ik} - \overline{x_i})(x_{jk} - \overline{x}_j)}{\sqrt{\sum_{i=1}^{n} (x_{ik} - \overline{x_i})^2} \sqrt{\sum_{j=1}^{n} (x_{jk} - \overline{x_j})^2}}$$

$\overline{x_i}$ is the average value of the i-th row of the matrix，and $\overline{x_j}$ is the average value of the j-th column of the matrix. The results of the numerical range are from -1 to 1. Higher value shows more similarity between two city nodes (Luo Jiade,1998). According to the results, we can divide the cities into four categories, namely Category 1: Shanghai, Hangzhou; Category 2: Shaoxing, Jiaxing, Taizhou, Ningbo, Zhoushan, Huzhou; Category 3:Yancheng, Nanjing, Hefei, Wuhu; Category 4:Zhenjiang, Wuxi, Suzhou, Nantong, Changzhou, Taizhou, Jinhua, Huai'an, Maanshan, Yangzhou. We marked them in Figure2.

Insert Figure2 here

In Figure2, all the cities in Category 2 are in Zhejiang province, and most cities in the Category 4 are in Zhejiang province. So we think that cities in the same province have more similarity rather then cities in different province. This shows that the administrative boundaries hinder the S.&T. cooperation of two cities.

3. Conclusions and Suggestions

Through the analysis of the S.&T. cooperation network of Pan-Yangtze River Delta, we discovered these following findings:This area has formed a network of S.&T. cooperation, and Shanghai is its central city, Hangzhou, Nanjing, Hefei, are the sub-central cities. Some cities are still marginalized in the network. As a example, Suzhou has the second bigger total economy, but its S.&T. cooperation with other cities still has great development potential. Hangzhou, Nanjing, Hefei are the sub-centre of the network, but the number of cities they cooperate with are small, and they need to expand their scope of cooperation.

Cities in the network have different structure and Shanghai, Hangzhou, Nanjing, Hefei and Suzhou is playing an intermediary role. A city with high degree intermediate can be a bridge to other cities in a large extent. So the use of the city with high Betweenness can promote the S.&T. Cooperation(Mintzberg H,1983). The administrative boundaries to some extent hinder the S.&T. cooperation between two cities. The non-core cities in the same province have a closer relationship on S.&T. cooperation, but it shows weaker between non-core cities in different provinces. For example, cities in Zhejiang province, or cities in Jiangsu province show more similarities on the S.&T. cooperation, but cities in Zhejiang province and another city in Jiangsu province show little similarities.

According to these findings we suggest that:

Though expanding channels of cooperation, innovating ways of cooperation, strengthening the density of Pan-Yangtze River Delta, the civic technological development and competitiveness can be promoted. Strengthen the intermediary role of cities such as Shanghai, Hangzhou, Nanjing, Hefei and Suzhou. Increase the capital investment and policy guidance to encourage these cities to expand their cooperation. Enhancing the central and radiation function of these cities. Focus on the regional collaboration and innovation of S.&T. policy, and gradually break the policy grid of S.&T. cooperation, and accelerate integration process of regional S.&T. cooperation.

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Figure1 S.&T. cooperation network diagram of cities

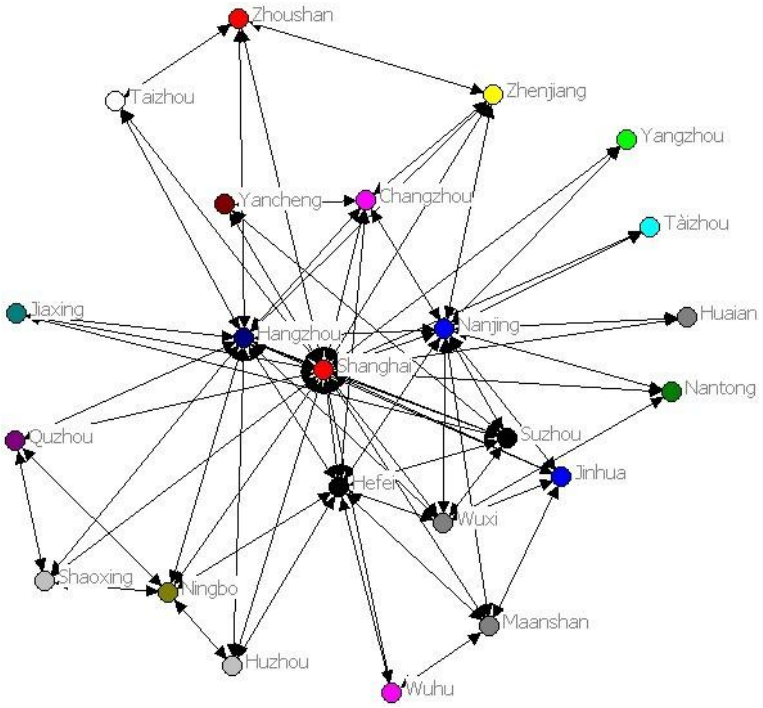

Table1. The Node Centralityof The Cities in the S.&T. Cooperation Network

ID	City	Node Centrality	ID	City	Node Centrality	ID	City	Node Centrality
1	Shanghai	100%	9	Zhenjiang	27.27%	17	Taizhou	13.64%
2	Hangzhou	68.18%	10	Maanshan	27.27%	18	Jiaxing	13.64%
3	Nanjing	59.09%	11	Jinhua	27.27%	19	Wuhu	13.64%
4	Hefei	45.46%	12	Huzhou	18.18%	20	Yancheng	13.64%
5	Wuxi	31.82%	13	Zhoushan	18.18%	21	Tàizhou	9.09%
6	Suzhou	31.28%	14	Quzhou	18.18%	22	Huaian	9.09%
7	Ningbo	27.27%	15	Shaoxing	18.18%	23	Yangzhou	9.09%
8	Changzhou	27.27%	16	Nantong	13.64%	24	-	-