Finance Industry Network Structure of Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract. This paper applies social network analysis methods to study the network structure of the finance industry in the Guangdong-Hong Kong-Macao Greater Bay Area. The paper applies gravity model to measure the connections intensity of financial industry, and analyze the network structure by social network method of networks visualization, centrality analysis, and cohesive subgroups. The results are as follows: (1) the development of the finance industry in the Greater Bay Area is gradually balanced; (2) the centers of the finance industry network in the Greater Bay Area are Guangzhou and Shenzhen, followed by Dongguan, Foshan, and Hong Kong; (3) finance industry network structure in the Greater Bay Area can be divided into five major subgroups, the main subgroups being the one of Guangzhou and Foshan, the one of Shenzhen and Hong Kong, and the one of Macau and Zhuhai. This paper finally concluded that the finance industry network structure in the Greater Bay Area is centered in Guangzhou and Shenzhen, and that Guangzhou, Shenzhen, and Hong Kong are closely connected, and other cities are loosely connected.

1. Introduction

As a national key regional development strategy, the construction of the Guangdong-Hong Kong-Macao Greater Bay Area has now entered the implementation stage, and certain progress has been made in infrastructure construction, institutional interoperability and in resource exchange. In the Greater Bay Area, the mainland region has a rich and strong manufacturing base, while Hong Kong and Macau have unique financial resources and international marketing platforms. Interregional connectivity can make international financial resources more effectively support the development of the Pearl River Delta manufacturing industry. Throughout the Greater Bay Area, Hong Kong, as one of the important global financial centers, has a strong financial platform advantage. And Macau's banking and insurance industries have also formed a unique financial advantage due to local system advantage. As the regional economic center of Guangdong, Guangzhou has the headquarters of many domestic finance institutions, and the Guangzhou Municipal Government is also committed to promoting the development of finance technology. As a high-tech innovation center in China, Shenzhen has closely integrated finance with corporate innovation. Shenzhen has a stock exchange and a rich finance ecosystem. Each region has its own characteristics of the finance industry and also has tight connections. In order to gain an in-depth understanding of the finance industry's liaison relationship between cities, as well as the city's position and characteristics in the overall network, this paper uses social network analysis to study the network association of the finance industry in the Greater Bay Area.
Social network analysis methods focus on examining the structure formed by individual relationships, and measuring the characteristics and relationships of individuals in the system to understand the distribution of relationships between individuals. Compared with traditional economic methods, it can avoid the study of only a single pair of objects in previous research. Therefore, when examining the economic problems of the relationships between individuals in a complex system, this method has its own advantages. Social network analysis methods have gradually been applied by many scholars, expanding from the original field of sociology to the fields of regional development, trade, and regional resource flows. For example, Lao Xin (2016) used social network methods and gravitational models to measure the economic connections between cities in the Yangtze River region, and analysed the nature of each city in the economic network; Zhuihui Hou (2009) used social network analysis to analyse the economic structure of the Yangtze River Delta urban agglomeration, and found that the degree of economic integration is not high, but there is a trend towards integration; Linqing Liu (2016) applied social network analysis to study relationships between the position characteristics of a single country in national level and found that the relationship is in an inverted U-shaped curve; Wang Xi et al. (2004) applied social network analysis method to study the evolution of the population network in the Yangtze River Delta from the perspective of population migration in cyberspace.

In addition, many scholars have also used social network methods to investigate the economic development of the Greater Bay Area. Wang Fangfang (2019) studied the economic positioning of cities in the Greater Bay Area using social network analysis methods using data of parent and subsidiary companies from listed companies, and found that the strength of the connection between the Bay Area city network and the density of inter-city company distributions showed a positive correlation; Jianjian Qiu (2019) used spatial measurement and social network analysis methods, from view of information flow and traffic flow, to identify and analyse the network structure characteristics of the Greater Bay Area. In addition, many scholars used network analysis methods to study the resource interconnection in the Greater Bay Area, mainly focusing on enterprise innovation. Peiyuan Xu (2019) used the data of research cooperation in the Bay Area cities to study the spatial evolution and formation mechanism of the knowledge innovation network structure; Wenhui Li (2019) based on cooperative patent application information, analysed the evolution process and mechanism of collaborative technology innovation in Guangdong-Hong Kong-Macao Greater Bay Area from different innovation dimensions.

From the research content, most scholars measure the links between cities by establishing a gravity model, but there is not much research focusing on specific industries in the Greater Bay Area. During the construction of the Greater Bay Area, the finance industry plays an important role in the upgrading and innovation of the manufacturing industry in the entire region. The construction plan in the Greater Bay Area also emphasizes the development of characteristic finance industries and promotes the interconnection of financial markets. Therefore, this paper selects the finance industry of the Greater Bay Area as the research object, and uses social network analysis to study the finance industry connection structure of the cities in the Greater Bay Area.

Based on the previous research and the characteristics of the finance industry, this paper selects appropriate variables to construct a gravity model, builds a finance industry connection network for urban agglomerations, and displays the network structure of the finance industry in the Greater Bay Area. By displaying the characteristics of the network, such as network visualization, centrality analysis, and subgroup analysis, the paper analyses the current state of the network structure of the finance industry in the Greater Bay Area.

2. Model and Data

2.1. Model Specification
In order to describe the finance industry connection between cities, this paper selects a gravity model to measure the connection intensity of finance industry between cities. The model is constructed as follows:
In the model, i and j represent different cities; G represents the GDP value of the city, P represents the population of the city, FIN represents the added value of the finance industry of the city, which is used to measure the finance industry level of the city, and D represents the economic distance between the cities.

In the model setting, in order to better reflect the gravitational connection between cities, the following processing was done: 1. Because the connection matrix of the city needs to be constructed by the gravitational model, due to the setting of the gravitational model, the gravitational forces between cities A and B and between B and A will be the same, but considering that the GDP and population of large cities such as Guangzhou, Shenzhen, and Dongguan in the Greater Bay Area are more prominent than other cities, which assumes gravity from these cities will be larger, the proportion multiplier of GDP is added to the gravity model to distinguish the degree of attraction between cities. 2. The economic distance between cities is an abstract concept, which includes not only geographical distance, but also the gap between different political backgrounds, systems, and cultures in the Greater Bay Area. Refer to previous scholars such as Meifang Peng (2015), Fangfang Wang (2018), and for the sake of simplicity, the highway distances between cities were selected as a measure of economic distance.

2.2. Social Network Analysis

Social networks are networks that individuals communicate for specific purposes. Social network analysis is a process that describes the relationship between individuals and estimates the value of the relationship. Social network analysis can provide mathematical analysis and visualization of the network for understanding the connections between individuals. Therefore, because social network analysis focuses on overall systematic research and the advantages of visualization, it can provide a convenient comprehensive perspective for studying each individual's position in the network and, moreover, the structural evolution. Therefore, in order to study the network structure of finance industry in the Greater Bay Area, this paper selects the following indicators for analysis:

2.2.1. Overall Network Analysis

The overall network uses the network structure to characterize the network structure. This paper combines the geographic information of the Greater Bay Area with the visualization of the network, and uses data in 2007 and in 2017 to provide an analysis for studying the finance industry connections of the Greater Bay Area.

2.2.2. Centrality

Centrality is used to express the centre degree of a node in the entire network. The centrality of a node is to measure its status in this network. The higher the degree of centrality, the more the individuals are connected to other individuals in the network. Common centrality measurement indicators include degree centrality, proximity centrality, and intermediary centrality.

2.2.3. Cohesive Subgroups

A subgroup refers to a collection of individuals in the network. There is a relatively strong, direct, and close relationship between the individuals in the collection. The subgroups are clustered according to the characteristics of individuals. The analysis of cohesive subgroups helps to simplify the complex
overall social network structure, to observe the neutron structure of the network and its relationships, and to grasp the internal state of the network.

2.3. Sample Selection and Data Sources
According to the definition in "Guangdong, Hong Kong, Macao Greater Bay Area Planning Outline", this paper selects 11 cities in the Greater Bay Area as research objects. The prefecture-level cities in the Pearl River Delta include nine cities: Guangzhou, Shenzhen, Foshan, Zhuhai, Dongguan, Zhaoqing, Jiangmen, Huizhou, and Zhongshan, plus two special administrative regions, Hong Kong and Macau.

In order to show the structural changes of the finance industry in the Greater Bay Area, this paper selected the cross-section data of 2007 and 2017. The economic data sources of the Pearl River Delta region are from the Guangdong Statistical Yearbook of the corresponding year, while the data of Hong Kong and Macao are from their statistical bureaus. The GDP of the Special Zone and the added value of the finance industry have been converted into RMB according to the exchange rate of that year. For the distance between cities, the shortest highways distance between cities is selected. The data comes from Baidu map.

3. Results

3.1. Network Structure
By constructing a gravity model, this paper firstly establishes a connection matrix for the finance industry in the Greater Bay Area, and then the matrix is applied to establish a corresponding connection network. Through UCINET software, a network structure of the finance industry in the region was drawn on the map of the Greater Bay Area. In order to better highlight the differences in connection strength between cities, this paper uses the natural discontinuity classification method, which is automatically divided into 4 levels according to the range of connection strength to highlights high-intensity connections. The natural discontinuity classification method is a commonly used clustering algorithm in geography. It can maintain the largest variance between groups and the smallest variance within a group after classification. By setting boundaries at locations with large numerical differences, the various clusters difference is maximized.

![Figure 1. Finance Industry Added Value Comparison between 2007 and 2017](image)

In Figures 1, the overall development intensity of the finance industry in the Greater Bay Area is constantly increasing. In 2007, only Guangzhou, Shenzhen and Hong Kong's finance industry added value formed a scale, while other cities' finance industry added value still had a large gap when compared with these three cities. Guangzhou and Shenzhen have attracted many companies and their headquarters due to their location in the economic centre of the Pearl River Delta, thus generating outstanding financial needs. Therefore, the finance industry has developed rapidly in these two cities
and has generated a high value-added in the finance industry. Guangzhou’s added value of the finance industry was 34.2 billion yuan, and Shenzhen was 77.9 billion yuan. As an international financial centre, Hong Kong is an important platform for Chinese companies to seek investment in the international market, so the finance industry is relatively developed. The added value of the finance industry was 20.3 billion yuan, accounting for about 20% of Hong Kong's total GDP. In the figure of 2017, we can see that Guangzhou, Shenzhen and Hong Kong's finance industries are still leading in the Greater Bay Area, while the gaps with other cities has narrowed. In 2017, the value added of the finance industry in Guangzhou, Shenzhen and Hong Kong was 199.8 billion, 305.9 billion and 43.4 billion, respectively. At the same time, the scale of the finance industry in Foshan and Dongguan closely follows Hong Kong. Its finance industry added value was 40.7 billion and 47.4 billion, and the finance industry in Huizhou, Zhuhai, Zhongshan and other cities also developed significantly. This shows that in the past 10 years of development, the finance industry in each city in the Bay Area has made great progress. It has gradually spread outward to other cities in the Greater Bay Area, from finance industry's originally centralized development in Guangzhou and Shenzhen to decentralized development in the whole area.

![Finance Connection Intensity between Cities in 2017](image)

**Figure 2.** Finance Connection Intensity between Cities in 2017

Figure 2 shows the finance industry network structure of cities in the Greater Bay Area. It is found that the financial and economic network structure of the Greater Bay Area has a strong proximity effect, and the main connection exists near the estuary of the Pearl River Delta. Obvious network intensity can be observed in between Guangzhou and Foshan, between Guangzhou and Dongguan, between Dongguan and Shenzhen, and between Shenzhen and Hong Kong. Traditionally, these cities have always had strong economic cooperation relationships, because of geographical proximity and cultural similarity. For example, Guangzhou and Foshan have always been complementary and cooperative in manufacturing, while Shenzhen and Dongguan have innovative and manufacturing contact. In addition, from the left side to the right side of the map, the more obvious intensities also exist in between Guangzhou and Jiangmen, between Guangzhou and Zhongshan, between Guangzhou and Hong Kong, between Foshan and Shenzhen, and between Hong Kong and Huizhou, indicating
that certain regions also have finance industries connection. However, due to geographical distance and economic volume, the intensity is not significant.

3.2. Centrality Analysis

Centrality can measure the direct relationship between the city and other cities. With more cities maintaining strong connection strength, the city will become the centre of the network and have a higher influence in the network. Commonly used centrality measurement indicators include degree centrality, closeness centrality, and betweenness centrality. Among them, the degree centrality is, for each single point, to calculate the number of other points directly connected to that point. The closeness centrality indicates the ability of this point to be an intermediate point. The calculation method is the geodesic of any other two points, and the ratio of the number of geodesics passing through this point. The geodesic is the shortest distance between any two points. The final approach to centrality is a measure of the betweenness of this point to all other points. The calculation method is the sum of the geodesic distances of this point and all other points. Because this paper builds the intensity of the finance industry connection between cities based on the gravity model, this paper does not consider the direction of the relationship in the calculation, and the intensity of the connection can be regarded as the number of connections between individuals. Therefore, only degree centrality was selected. The calculation results are as follows.

| City       | 2017 Network Centrality | 2007 Network Centrality |
|------------|-------------------------|-------------------------|
|            | Degree Centrality | Centrality Percentage | City       | Degree Centrality | Centrality Percentage |
| Guangzhou  | 25.162          | 0.27                   | Guangzhou  | 25.386          | 0.247                  |
| Shenzhen   | 18.835          | 0.203                  | Shenzhen   | 21.726          | 0.212                  |
| Foshan     | 15.069          | 0.162                  | Foshan     | 16.065          | 0.157                  |
| Dongguan   | 10.084          | 0.108                  | Dongguan   | 10.999          | 0.107                  |
| HongKong   | 6.62           | 0.071                  | HongKong   | 10.796          | 0.105                  |
| Zhongshan  | 4.46           | 0.048                  | Zhongshan  | 4.852           | 0.047                  |
| Jiangmen   | 3.922          | 0.042                  | Jiangmen   | 4.471           | 0.044                  |
| Huizhou    | 3.789          | 0.041                  | Huizhou    | 3.256           | 0.032                  |
| Zhuhai     | 2.262          | 0.024                  | Zhuhai     | 2.134           | 0.021                  |
| Zhaoping   | 2.159          | 0.023                  | Zhaoping   | 2.076           | 0.020                  |
| Macao      | 0.061          | 0.006                  | Macao      | 0.844           | 0.008                  |

In Table 1, both in the data in 2017 and in 2007, Guangzhou occupies a central position with a centrality of about 25.162 and a centrality ratio higher than 25%, followed by Shenzhen, Foshan and Dongguan. These four cities occupy more than 70% of the entire network structure, which means that the centre of finance industry structure in the Greater Bay Area is located near the Pearl River Delta with Guangzhou and Shenzhen as the core, forming a strong agglomeration. Guangzhou and Shenzhen have become the basis for financial development in the Greater Bay Area, driving and supporting the development of surrounding cities. In the future, the finance industry in the Greater Bay Area should give full play to the core advantages of Guangzhou and Shenzhen, and actively make use of the international financial influence of Hong Kong and Macau to further improve the finance industry in the Greater Bay Area.

Hong Kong, Zhongshan, Jiangmen, Huizhou and other cities maintain a certain relationship with the core cities. The average degree of centrality is about 4 and accounts for 4%. In 2007, the centrality of Hong Kong accounted for about 11%, but in 2017, due to the rapid growth and increase of finance industry in central cities such as Guangzhou and Shenzhen, Hong Kong's centrality drops. Finally, Zhuhai, Zhaoping, and Macau are in a relatively edge position in the entire network structure, and their finance industries scale need to be further developed.
3.3. Cohesion Subgroups

Using the CONCOR (Iterative Correlation Convergence Method) method in Ucinet, the cities in the Greater Bay Area were divided into subgroups. According to the intensity of the financial connection, the cities in the Greater Bay Area can be divided into 3 layers and 5 subgroups. In the classification of the lowest-level subgroups, the classification of the subgroups conforms to the position proximity, and it also conforms to the actual urban cooperative relationship. Among them, Guangzhou and Foshan, Shenzhen and Hong Kong, Zhuhai and Macau are grouped into a subgroup. These cities have very close economic cooperation due to their actual geographical proximity. Among them, Foshan leveraged Guangdong's finance high-tech zones to attract finance institutions in Guangzhou to land, and provided a series of financial services such as venture capital, credit ratings and IPO for manufacturing enterprises in Guangzhou and Foshan. Due to the geographical proximity of Zhuhai and Macau, financial cooperation is also very close. Zhuhai have a solid foundation in industries such as high-end manufacturing, medical, energy-saving and environmental protection, and infrastructure industries, and has an active equity financing, providing a good choice for equity investment funds set up by Macao capital. In the process of promoting economic and trade relations with Portuguese-speaking countries and the offshore RMB market of Portuguese-speaking countries, Macao can provide huge business space for Zhuhai finance companies. Hong Kong and Shenzhen form an organic cooperation in technology and finance, and vigorously promote financial support for high-tech incubation.

![Figure 3. Cohesion Subgroups Analysis of Cities in Financial Connection](image)

4. Conclusions and Policy Suggestion

4.1. Research Conclusions

This paper uses the data in 2007 and in 2017 to build finance industry relations between cities in the Greater Bay Area based on the gravity model. Through the analysis of the overall network, centrality analysis, and cohesive subgroup analysis, the analysis reached the following conclusions:

In the network structure, the financial development level of each city in the Greater Bay Area is constantly improving. The development of the finance industry has gradually changed from centralization to decentralization, and the traditional centre of Guangzhou and Shenzhen continue to radiate to the Bay Area. Due to the close relationship in economy cooperation and geography proximity, the financial connection in the region exist mainly in among Guangzhou, Shenzhen, Dongguan, and Hong Kong. The financial connection in cities such as Shaoguan, Zhuhai, Jiangmen, and Macau are not obvious.
In the analysis of the centrality, Guangzhou, Shenzhen, Dongguan, and Foshan occupy the centre in the network and have greater influence on other cities. However, cities such as Macau, Zhuhai and Huizhou are on the edge of the network and have insufficient influence on the network.

In the cohesion subgroup analysis, the cities in the Greater Bay Area can be divided into 3 levels and 5 subgroups. Among the subgroups, the relatively stable subgroups are Guangzhou and Foshan, Zhuhai and Macau, Shenzhen and Hong Kong, and the groups are in line with the actual situation of urban cooperation.

4.2. Policy Recommendations

First, it is necessary to further strengthen financial cooperation among cities in the Greater Bay Area and actively promote financial market interconnection. Many companies in the Greater Bay Area are joint customers of Guangdong and Hong Kong, and have diverse needs for cross-border financing. However, the financial regulatory supervision, financial system and legal framework of the Greater Bay Area are still very different. These disparities cause high costs for cross-region financing. Therefore, the unity of financial markets and institutions in the Greater Bay Area needs to be strengthened.

Second, it is needed to promote the financial development of the Greater Bay Area. When improving the level of the financial industry in the Greater Bay Area, it is necessary to actively utilize the leading role of core cities, and also pay attention to strengthening the connection of peripheral cities. According to the role and location of different cities in the Greater Bay Area, different targeted policies should be provided.

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