Research Paper

COMPARATIVE ANALYSIS OF BEIJING-TIANJIN-HEBEI URBAN AGGLOMERATION, YANGTZE RIVER DELTA URBAN AGGLOMERATION, GUANGDONG, HONG KONG AND MACAU BAY AREA BASED ON GRAVITY MODEL

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Abstract

Beijing-Tianjin-Hebei urban agglomeration, Yangtze River Delta urban agglomeration and the Guangdong, Hong Kong, Macau Greater Bay Area are China's three major urban agglomerations, including China's political, economic, financial and technological centers, which are important engines of the Chinese economy. The purpose of this study is to compare these three urban agglomerations from the economy, government management and spatial interactions. The major methodology of the study is gravity model. Since there are no clear official regulations for the scope of the three major urban agglomerations, we should define the scope and core areas at first, making them at a comparable level. First of all, the economy of the three major urban agglomerations in the wide-area range are similar, while the core area of Beijing-Tianjin-Hebei urban agglomeration is the weakest in per capita GDP. In the perspective of government management, the Beijing-Tianjin-Hebei urban agglomeration is policy-oriented and pays more attention to regional balanced development. The Yangtze River Delta urban agglomeration mainly focus on economic development. Under the policy of reform and opening up, Guangdong, Hong Kong, Macau Bay Area is seeking more regional cooperation with Hong Kong and Macau. In terms of spatial interactions, the Beijing-Tianjin-Hebei urban agglomeration presents a dual-core structure between Beijing and Tianjin. The other urban nodes in Hebei Province are not obvious, and the regional connections are weak, leading to unbalanced development. The Yangtze River Delta urban agglomeration presents the characteristics of a networked structure, and the cities in the entire region are closely connected and have a tendency to be integrated both in economy and transportation. The Guangdong, Hong Kong and Macau Greater Bay Area has formed a strong core composed of cities such as Guangzhou, Shenzhen, Hong Kong, Macau and Dongguan, which are closely linked with each other, but weakly connected with external region.

Keywords

Comparative analysis, urban agglomerations, gravity model

1. Introduction

Due to different translations and personal comprehension, scholars have a variety of understanding of the names of urban agglomerations and related concepts, such as megalopolis (Zhou, 1991), metropolitan interlocking region (Yu & Ning, 1983), and urban agglomerations (Gu, 2011). Although the name is different, most of them indicate that the urban agglomeration is an interconnected whole formed by cities of different grades, types and sizes, with the help of the regional transportation network. In this paper, we use “urban agglomeration” to refer to this phenomenon, and introduce the top three major urban agglomerations in China.

Beijing-Tianjin-Hebei urban agglomeration, Yangtze River Delta urban agglomeration, Guangdong, Hong Kong and Macau Bay Area are the top three urban agglomerations in China. The focus of our study is to introduce them from sizes and formation and development history. Then, we apply gravity model to examine the spatial interactions between cities inside the urban agglomerations, and how they act on the overall operation of the urban agglomeration.

The purpose of this study is to compare these three urban agglomerations from economy, government management and spatial interactions.

2. Theoretical Background of Spatial Interaction Models

Spatial interaction is a movement or transmission over space, which is resulting of a decision process involving different influences (Vobruha, Körner, & Breitenecker, 2016). This paper uses spatial interaction to measure the strength of economic linkages between regions. The spatial connection can reflect the radiation capacity of the central city to the surrounding area, and it can also reflect the acceptance of surrounding areas to central city (Meng, 2009).

Spatial interaction is widely studied in geography, urban science and other disciplines. For example, when determining the relationship between regions, Thünen suggests a concentric structure of crops distributed around urban areas from an agricultural perspective (1986). Weber explores the mechanism of industrial activity distribution from an industrial perspective (2002). Other studies, such as Perroux's growth pole theory (1950), Hagstrand's spatial innovation diffusion model (1967), Friedmann's "core-edge" theory (1966), etc. are all research and discussion on spatial interactions.

In the quantitative study of spatial interaction, two methods are commonly used: urban flow intensity and gravity model.

Urban flow generally refers to the flow of people, material, information, capital, technology and other elements within urban agglomeration. The formation of urban flow takes the regional transportation network as carrier, and city's radiation mechanism as the main driving force. Urban flow intensity is used to describe the quantitative impacts of urban outward function. Liang Chen and Zeng Jian (2019) used urban flow intensity model to study

the outward service function of Beijing-Tianjin-Hebei urban agglomeration. Lu Jun and Luo Qi (2017) used the urban flow theory to evaluate the traffic links and economic linkages of cities in Jiangxi Province using Tencent's location big data and traditional statistical data.

Gravity model is based on the gravitational equation of Newton's law of universal gravitation. In the gravitational equation, the gravity between two objects is positively related to mass and negatively related to distance. Henry Charles Carey (1852) first introduced gravity model to spatial connection studies when studying the issue of immigration behavior. Stewewart (Martin, 2008) uses gravity model to describe the magnitude of the population force between two regions. Subsequently, gravity model was widely applied in research on transportation, retail, immigration, and marketing. Since 1990s, Chinese scholars started to use gravity models to measure spatial interaction between cities or regions (Wang & Zhuang, 1996; Miao & Wang, 2006).

3. Methodology and Estimation Strategy

3.1. Construction of gravity model

In the study of spatial interaction, we need to consider the flow of people, logistics, technology, information between cities, which is a complicated process. Due to the poor availability of data such as technology flow and information flow, this paper compares spatial interactions of the three major urban agglomerations from population and economy.

$$G_{ij} = K_1 \frac{E_i E_j}{D_{ij}^b} + K_2 \frac{P_i P_j}{D_{ij}^b}$$

Where G_{ij} represents the gravity between two cities, E_i and E_j are the economic mass of city i and city j , P_i and P_j are population mass of city i and city j . D_{ij} refers to the distance between the two cities (in this article, we use linear distance). K is gravitational constant of each variable. This paper assumes that the role of the economy and population have equal influence on cities' external connection, so $K_1 = K_2 = 0.5$. b is the coefficient of friction, in this study, and $b=2$. By calculating the gravitational values of each city, we will get a gravitational matrix G_{ij} of three urban agglomerations.

3.2. Determination of the comprehensive influence of cities

Through the comprehensive gravity of the city, we can figure out the comprehensive influence of each city. The higher the gravity of the city, the higher the influence. The formula for the city's overall gravity is:

$$G_m = \sum_{i=1}^n G_{mi}$$

G_m represents the comprehensive gravity of city m . G_{mi} represents the gravity between city m and city i .

4. China's Three Urban Agglomeration

In the past 40 years, China's urban population has increased five times. In 2018, China's urbanization rate is close to 60%. China has a new plan to re-plan the national city map. According to the plan, China will promote large-scale urban agglomerations, and urban agglomeration will become the growth pole of economy in the future. At present, Beijing-Tianjin-Hebei urban agglomeration, Yangtze River Delta urban agglomeration and the Guangdong, Hong Kong and Macau Bay Area have become increasingly urbanized, and play very important roles in promoting regional development.

4.1. Defining the boundary of three agglomeration

Since the officially determined urban agglomerations are subjective and related to political strategies, the comparison of the three major urban agglomerations will results in large data bias. In order to ensure that the comparison is fair, we need to redefine the boundaries of the three major urban agglomerations so that they are at a comparable level. Through comprehensive consideration of population, GDP, and area, we finally obtained the scope of the three urban agglomerations (Tab.1), and defined core areas based on the level of urban development and regional influence (Tab. 2).

Table 1 Statistical Data of Urban Agglomerations

		Beijing-Tianjin-Hebei	Yangtze River Delta	Guangdong, Hong Kong and Macau Bay Area
Total Area	Area (10,000 km ²)	21.8 (Beijing/Tianjin/Hebei)	21.9 (Shanghai/Jiangsu/Zhejiang)	18.1 (Guangdong/Hong Kong/Macau)
	GDP (Trillion Yuan)	8.21	17.01	12.49/9.52 (Hong Kong, Macau Not Included)
	Population (10,000)	11159	16090	11980/ 11174 (Hong Kong, Macau Not Included)
	GDP Per Capital (Yuan)	73573	105718	104257/85198 (Hong Kong, Macau Not Included)

Source: Chinese Statistical Yearbook (2017)

Table 2 Statistical Data of Urban Agglomerations

		Beijing-Tianjin-Hebei	Yangtze River Delta	Guangdong, Hong Kong and Macau Bay Area
Core	Area	6.9 (5 Cities)	10.8 (16 Cities)	5.6 (11 Cities)

Area	(10,000 km ²)			
GDP (Trillion Yuan)	5.98	11.96	10.55/7.58	(Hong Kong, Macau Not Included)
Population (10,000)	6025	11154	6956/6150	(Hong Kong, Macau Not Included)
GDP Per Capital (Yuan)	99268	107193	151719/123265	(Hong Kong, Macau Not Included)

Source: Chinese Statistical Yearbook (2017)

Beijing-Tianjin-Hebei urban agglomeration is the weakest and most immature urban agglomeration among these three urban agglomerations. Although Beijing and Tianjin, two municipalities, are included in this area, the overall GDP is less than Guangdong, Hong Kong and Macau Bay Area without Hong Kong and Macau, and is half of the Yangtze River Delta urban agglomeration. The reason for its poor development is the lag of the integration of Beijing-Tianjin-Hebei, which we will elaborate later.

Yangtze River Delta urban agglomeration is the top one urban agglomeration with largest scale, greatest economy and highest level of integration in China. The development of cities is relatively balanced among three urban agglomerations. Shanghai ranks first in the country with more than 3 trillion yuan of GDP. At the same time, there are 4 cities have more than 1 trillion, and 7 cities have more than 500 billion. In the future, Shanghai will still be the core of this area, together with Nanjing, Hangzhou and Suzhou as the sub-centers. The integration process will keep going on.

In terms of GDP, the economic aggregate of Guangdong, Hong Kong and Macau Bay Area has become the second largest bay area in the world second to San Francisco Bay Area. In 2017, the GDP of Guangdong, Hong Kong and Macau Bay Area reached 12.49 trillion yuan. At the same time, Guangdong, Hong Kong and Macau Bay Area has the highest urbanization rate in China. In 2017, the urbanization rate is close to 85 %.

Figure 1 Beijing-Tianjin-Hebei urban agglomeration

Figure 2 Yangtze River Delta urban agglomeration

Figure 3 Guangdong, Hong Kong and Macau bay area

4.2. Formation and development

The three urban agglomerations are formed and developed under different circumstances, representing the different periods' political characteristics in China.

Beijing-Tianjin-Hebei urban agglomeration was formed with the support of national policies. Since the poverty problem in Hebei Province is very prominent, Chinese government plans to drive backward areas through developed regions, and has tried several regional integrations plans. "Bohai Economic Zone" is the earliest attempt. Initially, Bohai Economic Zone only included Beijing, Tianjin and Tangshan. In 1986, the Economic Union Mayor of the Bohai Economic Zone was established. In 1988, six cities including Beijing, Baoding and Langfang established the "Beijing Economic Cooperation Zone", starting a new attempt. In 2011, the National Development and Reform Commission proposed the establishment of the "Capital Economic Circle", including Beijing, Tianjin and, Baoding, Tangshan, Langfang, Shijiazhuang, Zhangzhou, Qinhuangdao, Zhangjiakou, Chengde, Handan, Xingtai, Hengshui of Hebei Province. Among them, Beijing, Tianjin, Baoding and Langfang are defined as central functional areas, having the prior developing opportunities. In 2015, the "Beijing-Tianjin-Hebei Collaborative Development Program" was approved. The target is to build a world-class urban agglomeration.

Yangtze River Delta urban agglomeration was spontaneously formed under the promotion of the market economy. With its developed land and water transportation conditions and abundant resources, the Yangtze River Delta has already had the prototype of the urban agglomeration in the middle and late period of China's feudal society. After the Opium War, foreign trade started in the Yangtze River Delta region due to its superior geographical position. Shanghai gradually became the trading center and a modern city of the time. After the reform and opening up, Yangtze River Delta seized this new opportunity of development. Shanghai is still the central city of the whole region, and the statuses of cities such as Hangzhou, Nanjing, Suzhou and Ningbo are also becoming increasingly important. It can be seen that the development of the Yangtze River Delta urban agglomeration is based on its

important transportation and trade resources, which makes the whole region open and grows in the market competition.

Guangdong, Hong Kong and Macau Bay Area is a successful work of the Chinese government to carry out reform experiments. From 1978 to 1985, in the early days of reform and opening up, Shenzhen, Zhuhai and Shantou were designated as special zones, directly undertaking industrial transfer in Hong Kong and Macau, forming a development model of “front and back factories” between Guangdong and Hong Kong, driving backward areas through developed regions. At that time, Shenzhen has become the economic center and innovative city of China from the original fishing village, and the urbanization rate has reached 100% recently. The take-off of Shenzhen has also led to the reform and development of the surrounding areas. Until now, Pearl River Delta region keeps exploring the path of innovation and creating a miracle, and becomes the region with the highest degree of openness and the strongest economic vitality in China.

5. Exploring Spatial Interaction of Three Urban Agglomeration

This paper uses the statistical yearbook data of three urban agglomerations in 2017 to establish the gravity model. Through the results of the gravity model, we can not only get the spatial interactions of the three urban agglomerations, but also form a network of connections between cities, which could be presented in the drawing and reflected spatial structures.

5.1. Model results of Beijing-Tianjin-Hebei urban agglomeration

The overall connection of Beijing-Tianjin-Hebei urban agglomeration is weak. Beijing and Tianjin form a strong twin core a radial relationship, affecting surrounding areas. The connection between cities is positively related to the physical distance. The closer the distance, the stronger the connection.

Beijing is closely connected with Tianjin, Langfang and Tangshan, and is weakly connected distant cities, such as Handan, Xingtai and Hengshui. Shijiazhuang, as the capital city of Hebei Province, is a sub-central city in the region. Shijiazhuang only has strong links with the well-developed Baoding, and cannot influence more areas around it.

As China's political, economic, science and technology center, Beijing has gathered resources all around the country. Tianjin has undertaken a series of national strategic projects and projects. The development environment of Beijing and Tianjin is better than Hebei province. However, their influences did not lead to the development of Hebei Province. The Beijing-Tianjin region is still in the agglomeration stage. People, finances and resources keep flowing to Beijing and Tianjin, especially to Beijing. Consequently, Hebei province lost its resources, and the economy of the region is extremely unbalanced. What's worse, the infrastructure such as transportation in Hebei province is also poor, limiting their further development, forming a “poverty belt” around Beijing. There is a huge gap from the goal of “building a world-class urban agglomeration”.

With the launch of the national plan of Xiong'an New District, it is expected to help Beijing ease the pressure and promote regional integration of Beijing-Tianjin-Hebei. Xiong'an New District is located in Baoding, Hebei Province, the hinterland of Beijing, Tianjin and Baoding, with obvious location advantages and convenient traffic. The development of Xiong'an New

District will assist on the optimization of the urban layout and spatial structure of Beijing-Tianjin-Hebei urban agglomeration, and complement the shortcomings of Hebei'. In the latest "13th Five-Year Plan", there has three high-speed rail will layouts from Beijing to Zhangjiakou, Beijing to Shenyang, and Beijing to Shangqiu, helping breaking the blind spots, and increasing the influence of central cities.

Figure 4 Spatial interaction of Beijing-Tianjin-Hebei urban agglomeration

In terms of the city's comprehensive influence, Beijing, Tianjin, Langfang and Tangshan have the greatest influence. These four cities are also well-developed areas in this region. Shijiazhuang's influence is at a medium level and has not exerted the influence as a provincial capital. Tangshan is an old industrial city of Hebei province, and its GDP is higher than Shijiazhuang. Langfang, located in the central part of Hebei province, has convenient access to the north and south, and its influence on surrounding areas is higher than that of Shijiazhuang. Shijiazhuang is just a small village in history. Due to the construction of railways in modern times, Shijiazhuang has become a "city on the train", traffic fortress and resource distribution center, and has favorable conditions for development. But compared to the old developed cities, Shijiazhuang's strength is relatively weak.

5.2. Model results of Yangtze River Delta urban agglomeration

Yangtze River Delta urban agglomeration has formed the initial shape of network structure, the internal links between cities are the strongest among the three urban agglomerations. Yangtze River Delta urban agglomeration has formed a high-intensity contact zone with "Shanghai, Nanjing, Hangzhou" as its core, and its regional influence is decreasing toward both sides along the "Shanghai-Nanjing" and "Shanghai-Hangzhou". The connection between Shanghai and Jiangsu is slightly stronger than the link with Hangzhou.

Shanghai is the core city of the region and the largest commuting destination. Suzhou residents are the main source of commuters to Shanghai, so Shanghai has the strongest contact with Suzhou. Also because of commuting, Shanghai has strong links with Nantong, Jiaxing and Zhenjiang. Shanghai's radiation range is almost all over the region, and is only weakly connected with marginal cities, like Lishui, Zhangzhou, Lianyungang, Suqian, Huai'an.

Hangzhou and Nanjing are the provincial capitals of Zhejiang province and Hangzhou province, respectively, and are secondary centers of urban agglomerations. They influence cities inside the province, and their connections with cities close to Shanghai are significantly stronger than those of marginal cities.

Figure 5 Spatial interaction of Yangtze River Delta urban agglomeration

The comprehensive influence of Shanghai, Suzhou, Wuxi, Changzhou, Nanjing, Nantong, Zhenjiang and Hangzhou in the region is in the high level of the urban agglomeration. Among them, Suzhou, Wuxi and Changzhou are close to Shanghai and have strong regional advantages. They are an important metropolitan area in the Yangtze River Delta urban agglomeration. At the same time, around Nanjing and Hangzhou, regional metropolitan areas have also been formed respectively, which plays a leading role in the surrounding areas.

5.3. Model results of Guangdong, Hong Kong and Macau Bay Area

Guangdong, Hong Kong and Macau Bay Area is the most dynamic and urbanized areas among three urban agglomerations. Shenzhen is the strong core. As the provincial capital of Guangdong Province, Guangzhou relies on political advantages to influence the surrounding areas. Hong Kong and Macau are the core area of the region because of their strong big economic strength and positive influence towards mainland China. Therefore, the spatial connection in the Greater Bay Area are mainly around Guangzhou, Shenzhen, Hong Kong and Macau.

However, uneven development still exists within the urban agglomeration. There is a serious gap between eastern and western sides of the Bay Area. Cities in core areas are closely linked, but cities far from the core area have weak connection. Compared with the Yangtze River Delta urban agglomeration, the radiation capability of the core area is obviously insufficient, and it is unable to provide more resources for the peripheral cities to promote their economy.

Figure 6 Spatial interaction of Guangdong, Hong Kong and Macau Bay Area

Shenzhen, Hong Kong, Dongguan, Guangzhou, Macau, Zhuhai and Foshan are the most influential cities in the region. In recent years, the integration processes between Shenzhen and Dongguan, Guangzhou and Foshan have been accelerating, and the boundary has become increasingly blurred, which are crucial the growth pole of the region. As an international financial, shipping and trading center, Hong Kong has a very comprehensive and mature international cooperation system, resources and experience, which is irreplaceable by any other cities in the Bay Area. Macau is a customs zone that implements low-tax policy. Macau has the superiorities of flexibility, convenience and affordability in finance, and will play an important role in the foreign trade of the Bay Area. Zhuhai is the only city connected with Hong Kong and Macau by Pearl river delta bridge. Zhuhai is a significant node in the cooperation between Hong Kong, Macau and mainland.

6. Conclusion

6.1. Comparison of three urban agglomeration

The integration of the Yangtze River Delta urban agglomeration, and Guangdong, Hong Kong and Macau Bay Area is obvious, and major cities are tightly related to each other. In contrast, the Beijing-Tianjin-Hebei urban agglomeration is concentrated in Beijing and Tianjin, other cities are distributed isolated in the region and rarely connect with outside cities. By comparing the night light indices of the three urban agglomerations, our conclusions are once again confirmed:

In the night light index of the Beijing-Tianjin-Hebei urban agglomeration (Figure 7), we can see more clearly that the Beijing-Tianjin region has a very high light index and is concentrated in central cities. The integration trend is clear and obvious. Most cities in Hebei are scattered around in the form of points and have not been fully developed.

Yangtze River Delta urban agglomeration has the most massive night light coverage (Figure 8). Night lights in the core area are beyond borders of the city and have a tendency to be one part. The brightness of other cities is also higher than that of other urban agglomerations.

Guangdong, Hong Kong and Macau Bay Area has a strong core around Guangzhou, Shenzhen, Hong Kong, Macau, Dongguan and Zhuhai (Figure 9). Like Yangtze River Delta urban agglomeration, it has broken through borders and gradually joined together. The lights in the peripheral cities are obviously dim and scattered.

Figure 7 Night light index of Beijing-Tianjin-Hebei urban agglomeration

Figure 7 Night light index of Yangtze River Delta urban agglomeration

Figure 7 Night light index of Guangdong, Hong Kong and Macau Bay Area

6.2. Future improvement suggestions

The gravity model of this paper also has room for improvement.

This paper studies the linear distance between cities, and does not consider the situation of attenuation with distance. In the future, distance could be taking into account in the model.

The gap between cities is not only a result of economy and population of the city, but also affected by many factors such as education, medical care, and infrastructure construction. Therefore, more variables can be added in the future to measure the connections between cities.

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