Empirical analysis of the spatial relationship between urban agglomeration economic network and economic growth based on big data

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Abstract. A reasonable and orderly network space structure is an important support for the coordinated economic development of urban agglomerations. Based on the urban panel data of the three major urban agglomerations in the economic belt from 2010 to 2019, this paper first uses social network analysis methods to quantitatively identify the cyberspace characteristics of the three major urban agglomerations. On this basis, a spatial measurement model was constructed to test the heterogeneous influence of the network space structure and the coordinated economic development of the three major urban agglomerations. The results show that after controlling the relevant influencing factors, the improvement of the urban agglomeration's spatial network level has a direct promotion effect on its coordinated economic development, but the indirect spatial spillover effects show obvious differences. Among them, the higher the level of networking, the more obvious the positive spatial spillover effect, and the higher the level of coordinated economic development of the urban agglomeration. Therefore, strengthening the network connection between cities and forming a closely connected and functionally complementary urban agglomeration network spatial structure is conducive to giving full play to the positive spatial spillover effect and realizing the coordinated economic development of the urban agglomeration.

1. Introduction

With the continuous advancement of my country's industrialization and urbanization, the regional economic development form and competition pattern dominated by urban agglomerations have become an important feature of economic operation[1]. Under the background that the problem of uneven and insufficient regional economic development is still prominent, promoting the coordinated development of regional economy with urban agglomerations as the mainstay has become an important strategic choice for economic development[2]. The academic circles believe that the essence of urban agglomeration is the embodiment of urban spatial form in the process of regional integration [3], behind this form reflects the spatial distribution of resources, elements, and social and economic activities and the combined state. The coordinated development of regional economy at the spatial scale of urban agglomerations means that the free flow and optimal allocation of resources and elements between the inner cities have also formed a functional differentiation pattern with industrial division and cooperation as the main content [4]. With the continuous advancement of the globalization process and the rapid progress of transportation information technology, the speed and direction of the flow of various elements between cities are undergoing fundamental changes. The
economic links between cities have gradually changed from two-way, linear correlation to a whole, with the transformation of multi-directional and cross-connected network economy, large, medium and small cities are forming a city network system with certain functions and structural connections. In this dynamically evolving structural system, the central city not only continuously attracts the population and element resources of small and medium-sized cities to flow to the central city under the power of spatial agglomeration, bringing more favorable opportunities for its development, but also under the influence of proliferation power\[5\]. Promote the development of surrounding small and medium-sized cities by accelerating the flow of factors and advancing the division of labor; small and medium-sized cities are embedded in the urban agglomeration network supported by central cities to achieve "scale borrowing" and "function borrowing" to make up for their own lack of scale and functions single disadvantage. As the urban agglomeration network becomes more and more closely connected, cities at all levels carry out information connectivity, resource sharing, and industrial division of labor based on their own development needs, thereby forming a gradual benefit sharing mechanism[6]. The internal economic development gradually evolves to a coordinated state, and finally reaches a dynamic balance. This article emphasizes the supporting and leading role of the three major urban agglomerations in the Yangtze River Economic Belt, including the Changjiang Triangle City Group, the Yangtze River Midstream City Group, and the Chengdu-Chongqing City Group. However, due to different factors such as geographical conditions, factor endowments, and development stages, the three major urban agglomerations not only differ significantly in cyberspace characteristics, but also the degree of imbalance in the internal urban economic development is very prominent[7]. Especially after the development of regional integration in the Yangtze River became a national strategy, country's regional coordinated development has entered a new historical stage, and urban agglomeration-scale integration has gradually become an important task to promote regional coordinated development. Therefore, objectively examining the differences in the cyberspace structure of the three major urban agglomerations and testing the heterogeneity of their impact on the coordinated economic development of the urban agglomerations is important for further optimizing the spatial structure of the urban agglomerations and supporting a higher level of coordinated regional economic development. The mechanism of urban agglomeration economic linkages and spatial spillover effects of economic growth is shown in Figure 1.

\[\text{Figure 1. Economic linkages of urban agglomerations and spatial spillover effects of economic growth mechanism}\]
2. Measurement and comparative analysis of urban agglomeration network spatial structure

2.1. Analysis of overall network characteristics

The spatial structure of urban agglomerations is a spatial organizational structure formed on the basis of interconnections and interactions between cities. It has the characteristics of clustering and networking, and measurement indicators must be able to effectively capture these core characteristics. Based on the research of [6], this paper uses the social network analysis of the gravity model to measure the economic network connection between any two cities in the urban agglomeration calculate the total amount of interaction between a city and all other cities in the city group.

\[ x_{ij,t} = \sqrt{A_i A_j B_i B_j} / \rho_{ij} \]  

(1)

Among them, \( x_{ij,t} \) are the gravitational values between city \( i \) and city \( j \) in period \( t \), which is called the economic network connection quantity here. \( A_i \) and \( B_i \) are respectively the urban population scale and GDP scale of city \( i \) in the city cluster in period \( t \), \( \rho_{ij} \) is the geographic distance between city \( i \) and city \( j \).

The total economic network connections of a city agglomeration reflect the sum of the economic network connections between a city and all other cities in the city agglomeration. This article expresses the degree centrality in the social network theory. This also measures the node status of a city in the city cluster network. The stronger the degree of centrality, the higher the node status of the city. Therefore, according to the calculated gravitational value between cities, the Ucinet software is used to further calculate the total economic network connection \( S_{ij} \) of city \( i \) in period \( t \), and the calculation formula is as follows[7]:

\[ S_{ij} = \sum_j x_{ij,t} \]  

(2)

When portraying and describing the overall network spatial structure of urban agglomerations, this article uses ArcGIS 10.2 to draw the urban economic network connection pattern of the three major urban agglomerations in 2016 based on the calculated inter-city economic network connections and total economic network connections.

2.2. Network density

Network density is an important indicator used to reflect the degree of perfection of the city network and the closeness of the interaction between the nodes and cities in the network. The greater the network density, the closer the connections between cities and the better the city network. The calculation formula is:

\[ \rho_t = \frac{\sum_i \sum_j x_{ij,t} / n(n-1)}{n} \]  

(3)

where \( \rho_t \) is the network density of the city agglomeration at period \( t \); \( x_{ij,t} \) is the distance between city \( i \) and city \( j \) in the city agglomeration network at period \( t \). The number of economic network connections, \( n \) is the number of cities in the city cluster network.

![Figure 2. The network density of the three major urban agglomerations in the Yangtze River Economic Belt from 2010 to 2019](image-url)
It can be seen from Figure 2 that from 2010 to 2019, the urban network density of the three major urban agglomerations has changed significantly, and the network space structure has gradually become more complex. The network density of the Yangtze River Delta urban agglomeration increased from 0.12 to 0.76, the Yangtze River mid-stream urban agglomeration increased from 0.02 to 0.16, and the Chengyu urban agglomeration increased from 0.03 to 0.36, indicating that the three major urban agglomerations The network connection pattern is showing a rapid expansion trend. In addition, the network density of the three major urban agglomerations has significant differences in the size and trend of change. The network density of the Yangtze River Delta urban agglomeration is not only always higher in size than the middle reaches of the Yangtze River and Chengdu-Chongqing urban agglomerations, but the growth rate is also much higher than the other two City clusters. The network density of the Chengdu-Chongqing urban agglomeration is slightly higher than that of the middle reaches of the Yangtze River. It shows that the network structure of the three major urban agglomerations is significantly different. The Yangtze River Delta urban agglomeration has a higher degree of networking and the closest inter-city connections; the Chengdu-Chongqing urban agglomeration is second; the middle reaches of the Yangtze River has the lowest network density and weaker inter-city connections.

3. Analysis of model results

3.1. Establishment of spatial measurement model

The spatial structure is a function of economic and social development. In regional science and urban economics, many studies use the overall production function at the city level to examine the external effects of urbanization and the economic performance of the spatial structure. Following [8] to investigate the modeling idea of spatial structure economic performance, this paper uses the generalized Cobb Douglas (C-D) production function for benchmark modeling. The function form is as follows:

\[ Y = a \cdot Q^\alpha \cdot W^\beta \cdot E^\gamma \cdot R^\delta \cdot T^\epsilon \]  

(4)

\( Y \) stands for nominal output, \( a \) stands for efficiency parameters, here are mainly used to reflect the performance parameters of the spatial structure, \( Q, W, E, R, \) and \( T \) respectively represent physical capital, labor, human capital, intermediate inputs, and other factors that affect economic output the elements of. The above formula is further transformed into the form of per capita output (income):

\[ \frac{Y}{W} = a \cdot \frac{(Q/W)}{\alpha} \cdot \frac{(E/W)}{\beta} \cdot \frac{(R/W)}{\delta} \cdot \frac{(T/W)}{\epsilon} \]  

(5)

Take the logarithm of both sides into linear form:

\[ \ln(Y/W) = a \cdot \ln\left(\frac{Q}{W}\right) \cdot \alpha \ln\left(\frac{E}{W}\right) \cdot \beta \ln\left(\frac{R}{W}\right) \cdot \delta \ln\left(\frac{T}{W}\right) + \sum \ln(x_i) \]  

(6)

In the above equation, \( a \) represents a series of variables related to the spatial structure and entering the production function. Since this article focuses on the relationship between the urban agglomeration network spatial structure and its economic coordinated development, the spatial econometric model is adopted in the setting of the specific econometric model. According to[8], the Spatial Dubin Model (SDM) has many advantages over other forms of spatial models such as SEM and SAR, and can better reveal the direct and indirect effects of related influencing factors. Spillover effect and total effect which are more in line with the research needs of this article. For this reason, based on the aforementioned Cobb Douglas overall production function benchmark model, the following econometric test model is set:

\[ \ln Y_{it} = aW \ln y_{it} + \alpha \ln aN_{it} + \beta \ln x_{it} + \epsilon \ln aN_{it} + W \ln(x_{it}) + \epsilon \]  

(7)

Among them, the subscript \( i \) represents the city, \( t \) represents the period, and \( y \) is the explained variable, that is, the level of coordinated economic development of the urban agglomeration. Here, the relative per capita income of the city is used as its proxy variable. \( W \) is the spatial weight matrix, and \( W_{ijt} \) is the
spatial lag of the explained variable, which is used to reflect the spatial correlation impact of the relative per capita income level between cities. The core explanatory variable $aN_t$ is the centrality of the urban network node, and $WaN_t$ is the spatial lag term of the centrality of the urban network node, which is used to capture the spatial spillover effect of the weighted network node centrality of other cities on the city. $X_t$ is a set of control variables. $\epsilon$ is the random disturbance term. $\alpha$ is the spatial lag coefficient; $\chi$ is a spatial measure of the spillover effect of urban network node centrality on local relative income per capita. If the estimated value is significantly positive, it means there is a positive spillover effect; if it is negative, it means there is a negative spillover effect.

3.2. Data sources

This paper uses the three major urban agglomerations in the Yangtze River Economic Belt as the investigation unit. The sample cities involved in the study include the Yangtze River Delta urban agglomeration, the Yangtze midstream urban agglomeration, and the Chengdu-Chongqing urban agglomeration. The data mainly come from the 2010-2019 China Urban Statistical Yearbook, China Urban Construction Statistical Yearbook and the statistical yearbooks of various provinces and cities, and the statistical caliber of the city jurisdiction is adopted uniformly, that is, the main urban areas including urban and suburban areas. Urban GDP data is deflated using price index, and foreign direct investment data is converted using average exchange rates over the years. Considering the consistency of the dimensions, and in order to eliminate heteroscedasticity, the variables are logarithmized.

3.3. Model selection and estimation methods

In the selection of the panel data model, this paper uses Hausman's test and comparison of the estimated results of the fixed-time, individual-fixed and dual-fixed models, and chooses the fixed-time effect. In the choice of spatial measurement model, based on Lagrangian multiplier (LM) test, robust LM test and log likelihood ratio (LR) test, it is found that the spatial Durbin model can better fit the data in this paper. Due to the existence of the lag term in the spatial Durbin model, if the traditional least square estimation is adopted, inconsistent estimation results will be obtained. According to the suggestions of [9], this paper uses the maximum likelihood estimation method (ML) to estimate, and regresses the spatial Durbin model based on the geographical distance matrix and the economic connection matrix respectively. Table 1 shows the estimated results of direct effects, indirect effects (spillover effects) and total effects of the spatial Dubin model.

Table 1. The spatial measurement regression of the spatial structure of the three major urban agglomerations and the impact of coordinated economic development

| Variable | Yangtze River Delta City Group | City Groups in the Middle Reaches | Southwest City Group |
|----------|-------------------------------|----------------------------------|----------------------|
|          | $W(1)$ $W(2)$ | $W(1)$ $W(2)$ | $W(1)$ $W(2)$ |
| Direct effect | 0.131 0.154 | 0.120 0.168 | -0.015 -0.027 |
| Indirect effect | 0.954 2.175 | 0.455 0.818 | 0.321 0.518 |
| Total effect | 0.428 1.745 | -0.125 0.221 | 0.076 0.548 |
| $P$ | 0.025 0.204 | 0.112 0.486 | 0.085 0.045 |
| $R^2$ | 0.751 0.754 | 0.798 0.754 | 0.355 0.195 |
| Log L | 84.51 98.45 | 76.54 74.81 | 135.89 138.74 |
| Obs. | 305 305 | 345 345 | 179 179 |

In Table 1, from the estimation results and other statistics, the spatial Durbin model has a good degree of fit and can more accurately capture the impact of the urban agglomeration network spatial structure and its economic coordinated development.
Figure 3. The spatial measurement regression of the spatial structure of the three major urban agglomerations

From Figure 3, under the two spatial weight matrices of W (1) and W (2), the estimated spatial lag coefficient of the three major urban agglomerations differ significantly in direction and significance level. When the study tested the spatial convergence of different urban agglomerations, it was found that the Yangtze River Delta urban agglomerations showed significant spatial correlation, including Chengyu Other national-level urban agglomerations did not show obvious spatial interaction. Secondly, after controlling for the influence of related variables, the direct effects, indirect effects and total effect estimation coefficients between the urban network node centrality of the three major urban agglomerations and their coordinated economic development are significantly different in direction and significance. It shows that the improvement of the central status of urban network nodes not only increases their own relative income levels through direct growth effects, but also produces positive spatial spillover effects, which significantly increase the relative income levels of neighboring cities, and the latter has a stronger effect than the former.

Figure 4. The impact of coordinated economic development

From Figure 4, cities use "scale borrowing" and "function borrowing" to obtain the benefits brought by the improvement of the network node status of neighboring cities. When the status of the urban network center increases, the level of urban agglomeration networking will increase accordingly. Under the effect of economies of scale and agglomeration, central cities will continue to gather the elements and resources of surrounding cities to achieve an increase in their relative income levels;
they are also spreading power. Under the role of, give full play to the positive spatial spillover effect to drive the increase in the income level of surrounding cities, and promote the reduction of the income gap between cities, and the power of the latter (spatial spillover effect) is greater than the former (node agglomeration effect)[10].

4. Conclusion

As an important space carrier for optimizing the spatial layout of cities and realizing coordinated development of regional economy in the new era, urban agglomerations present different spatial forms due to differences in regional space and stages of development, and there are obvious differences in the level of coordinated economic development. Therefore, the three major urban agglomerations in the Yangtze River Economic Belt are the research objects of this paper. First, the network spatial structure of the three major urban agglomerations is measured based on the social network analysis method. The results show that the direct growth effect caused by the promotion of the status of urban network nodes in the three major urban agglomerations is widespread, but the spatial spillover effect is obviously different in the direction and intensity of the role due to the difference in the spatial structure of the network, thus harmonizing the urban agglomeration economy. The more networked cities in the urban agglomeration, the more obvious the positive spatial spillover effect, and the higher the level of coordinated economic development of the urban agglomeration.

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