Study on the Influence of Urban Spatial Connection of Beijing Tianjin Hebei Urban Agglomeration on Total factor Productivity

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Abstract. The development of a city cannot be separated from the connection with the outside world. A city can benefit from the external effect of the connection network with other cities. This paper studies the relationship between cities’ connection strength and TFP according to the network centrality index, which measures the level of the connection between cities. It is found that the connection between cities has a significant positive role in promoting the TFP of cities in a city cluster. The differences of labor scale, industrial structure and openness are the main factors that affect the connection between cities.

1 Introduction

In the urban network system, whether individual cities can benefit from the urbanization economy under the influence of network has not formed a consensus in academia. Some scholars believe that the gradually strengthened intercity connection can enlarge the economic effect of urbanization, that is, it can break through the limitation of individual city’s own factors and have a positive effect on the city.\(^1\) As for the network effect of urban agglomerations, some scholars have a concept, that is, the externality of urban networks, and they stress that this effect will affect the whole urban agglomerations. Suwala (2013) believes that the intercity connection will create convenience for the actors at all levels in the urban agglomeration, such as enterprises, social organizations, individuals.\(^5\) In the existing research, a large number of research results show that the participation of individual cities in the network is significantly related to their economic benefits.\(^4\) There are even views that the contribution of external connections to the effect of urban development has exceeded its individual internal conditions.\(^5\) Some domestic scholars have studied the relationship between regional spatial connection and regional economic growth, for example, Zhao (2015) finds that interregional linkages and spatial spillovers have a significant impact on regional economy;\(^6\) Li (2014) studies the spatial connection of economic growth based on the provincial data over 30 years since the reform and opening up, and the results show that the network structure of economic spatial growth is stable;\(^7\) Miao (2018) studies the influence of the strength of regional overall connection on regional economic efficiency with ten major urban agglomerations in China.\(^8\)

To sum up, literature did little research concerning urban agglomeration and linkages’ impact on specific city’s economic efficiency. This paper tries to do some work in this field. With the yearly data of 2007, 2013 and 2017, the authors study the impact of urban spatial linkages on Total Factor Productivity (TFP), a commonly used measure of economic efficiency, in Beijing, Tianjin and Hebei.

2 Research method

2.1 Social network analysis

The central analysis in social network analysis can analyze the characteristics of each city's connection network. This paper uses this kind of index to measure the current situation of each city's external connection. Centrality is used to describe the central position of cities in the network. Cities in the center of the network are more convenient to access resources and information, and have greater power and influence. In this paper, the three most common centrality indicators are selected for analysis.

1. Degree centrality: among the direction of economic connections, this indicator can be divided into outgoing degree and incoming degree, which respectively represent the degree of impact sent out and the degree of impact received. The calculation formula is shown in formula (1):

\[
C\text{(out)}_i = \frac{d\text{(out)}_i}{k-1}, \quad C\text{(in)}_i = \frac{d\text{(in)}_i}{k-1}
\]

In the formula, \(C\text{(out)}_i\) is outgoing degree of \(i\), \(C\text{(in)}_i\) is incoming degree of \(i\), \(d\text{(out)}_i\) is the number of outgoing connections of \(i\), \(d\text{(in)}_i\) is the number of incoming connections of \(i\), \(k-1\) represents the number of theoretical connections between a point and the outside when the number of subjects is \(k\).

2. Closeness centrality: it measures the proximity of the connection distance between nodes. The closer they are, the less controlled they are by other nodes. The

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specific calculation formula is shown in formula (2):

\[ C_{c(i)} = \left( \sum_{j=1}^{n} d_{ij(c)} \right)^{-1} \]  

(2)

In the formula, \( d_{ij(c)} \) represents the distance between \( i \) and \( j \), and the economic distance is used in this paper. The greater the proximity to the center, the higher the proximity to other cities.

3. Betweenness centrality: a measure of the "media" function of a node's connections. The only way to connect cities is often the throat, which can control the connection of other cities. The formula is shown in formula (3):

\[ C_{b(i)} = \sum_{j<k} \frac{g_{jk(i)}}{g_{jk}} \]  

(3)

2.2 Stochastic Frontier Analysis

In this paper, TFP represents economic efficiency with stochastic frontier analysis (SFA) as the calculating method. SFA, which decomposes the error term, is more suitable for the research of cross period panel data and the conclusion is more in line with the real situation10.

Based on the three factors input hypothesis, this paper selects three input indicators, namely, material capital input, land input and labor input. To prevent results deviation, this paper has two indicators, the regional GDP and the urban fiscal revenue, represent output.

On input indicators. First, material capital investment. At present, the official statistical department has no special statistical data, and most of the studies in China and abroad adopt the perpetual inventory method. The principle is to treat the relative efficiency as a geometric decline, and set the replacement rate as a constant, then the capital stock of this year = the capital stock of the previous year × (1-depreciation rate) + the investment of this year. Based on the research methods and preliminary estimation results of Dan (2008) 11, Sun et al. (2017) 12, this paper uses the national income of each city in 2007 to get the capital stock of that city in 2006, and then calculates the capital stock of the city over the years according to the capital stock in 2006 and the total fixed asset investment in that year. Second, land investment, this paper selects the land factors closely related to urban economic activities, and obtains the total built-up area of the city included in the urban agglomeration. Third, labor capital is measured by the number of employees in the statistical yearbook of each city.

3 Empirical analysis

3.1 Index calculation

3.1.1 Intercity connection

The economic connection matrix calculated based on the modified gravity model is imported into ucinet6.212, and the network centrality index data of urban nodes are processed, as shown in Table 1. Limited to space, the specific calculation results of the economic contact matrix are not listed.

| Rank | Degree centrality |  |  
|------|------------------|--|--
|      | Outgoing degree  |  |  
|      | Incoming degree  |  |  
| 1    | Beijing          | 94.44 | 55.55 |
| 2    | Tianjin          | 72.22 | 44.44 |
| 3    | Shijiazhuang     | 61.11 | 44.44 |
| 4    | Cangzhou         | 44.44 | 44.44 |
| 5    | Tangshan         | 38.88 | 44.44 |
| 6    | Jinan            | 38.88 | 44.44 |
| 7    | Baoding          | 33.33 | 44.44 |
| 8    | Handan           | 33.33 | 38.88 |
| 9    | Zhengzhou        | 33.33 | 38.88 |
| 10   | Langfang         | 27.77 | 33.33 |
| 11   | Hengshui         | 27.77 | 27.77 |
| 12   | Xingtai          | 22.22 | 22.22 |
| 13   | Taiyuan          | 22.22 | 22.22 |
| 14   | Anyang           | 11.111| 16.66 |
| 15   | Zhangjiakou      | 5.556 | 16.66 |
| 16   | Qinhuaondon      | 5.556 | 11.111|
| 17   | Chengde          | 0     | 11.111|
| 18   | Shenyang         | 0     | 5.556 |
| 19   | Huhhot           | 0     | 5.556 |

Table 2. Closeness centrality

| Rank | Closeness centrality |  |  
|------|----------------------|--|--
|      | Outgoing degree      |  |  
|      | Incoming degree      |  |  
| 1    | Beijing              | 97.22 | 68.51 |
| 2    | Tianjin              | 86.111| 62.96 |
| 3    | Shijiazhuang         | 80.55 | 62.96 |
| 4    | Cangzhou             | 72.22 | 62.96 |
| 5    | Jinan                | 69.44 | 62.96 |
| 6    | Tangshan             | 68.51 | 62.96 |
| 7    | Baoding              | 66.66 | 62.96 |
| 8    | Langfang             | 62.96 | 60.18 |
| 9    | Handan               | 61.111| 60.18 |
| 10   | Zhengzhou            | 61.111| 57.40 |
Table 3. Betweenness centrality

| Ranking | Betweenness centrality |
|---------|------------------------|
| 1       | Beijing 27.394          |
| 2       | Shijiazhuang 16.236     |
| 3       | Tianjin 8.907           |
| 4       | Tangshan 6.064          |
| 5       | Handan 6.011            |
| 6       | Jinan 4.781             |
| 7       | Cangzhou 3.087          |
| 8       | Baoding 3.038           |
| 9       | Xingtai 2.768           |
| 10      | Hengshui 1.534          |
| 11      | Zhengzhou 0.558         |
| 12      | Langfang 0.448          |
| 13      | Taiyuan 0.218           |
| 14      | Chengde 0               |
| 15      | Zhangjiakou 0           |
| 16      | Qinhuangdao 0           |
| 17      | Anyang 0               |
| 18      | Shenyang 0              |
| 19      | Huhhot 0               |

Table 3. Betweenness centrality

3.1.2 Total Factor Productivity

According to the C-D production function, the stochastic frontier model is constructed, and the basic model is as follows:

\[ \ln Y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln N_{it} + \beta_4 t + (\mu_{it} - \mu) \]

\[ \mu_{it} = \mu \exp \left[ -\eta (t - T) \right] \tag{4} \]

In the formula, \( Y_{it} \) represents urban output; \( K_{it}, L_{it}, N_{it} \) represent capital input, labor input, and land input respectively; \( \mu_{it} \) is random interference term and obeys normal distribution \( N(0, \sigma_\mu^2) \); \( \mu \) is a term of technical inefficiency and obeys the non-negative tail breaking normal distribution \( N^+(\mu, \sigma_\mu^2) \); \( \eta \) is the rate of change of the term of technical inefficiency.

Using FRONTIER4.1 software, the estimated values of each parameter and technical efficiency (TE) of the model are obtained. The estimated results of the model are shown in Table 4.

Table 4. Estimation Results of SFA Panel Data Model

| Item       | Coefficient | Standard error | T statistic |
|------------|-------------|----------------|-------------|
| Constant term | -0.1308     | 1.2191         | -1.2371     |
| LnK        | 0.3330      | 0.0891         | 3.7368      |
| LnL        | 0.1208      | 0.0675         | 1.8789      |
| LnN        | 0.9055      | 0.2034         | 4.4744      |
| t          | 0.2911      | 0.1070         | 2.7194      |
| Sigma-squared | 0.1929     | 0.0527         | 3.6604      |
| Gamma      | 0.8981      | 0.0414         | 21.6907     |
| Mu         | 0.8326      | 0.1722         | 4.8340      |
| Eta        | 0.1650      | 0.5827         | 0.2832      |
| Log-likehood | 3.0902     | 43.0315        |             |

Note: *** represents significance level < 0.01, ** represents significance level < 0.05, * represents significance level < 0.1.

It can be seen from the table that the fitting degree of the model is good. Among them, \( \gamma = 0.8981 \) indicates that the model has an obvious composite error structure, indicating that the stochastic frontier model is more suitable for production function estimation than the traditional econometric model.

According to the definition of TFP, TFP of each region can be calculated by formula 5. The results are shown in Table 5.

Table 5. Total factor productivity and its decomposition

| City          | 2007  | 2013  | 2017  |
|---------------|-------|-------|-------|
| Beijing       | 1.0638| 1.4250| 1.9064|
| Tianjin       | 0.6753| 0.9113| 1.2191|
| Shijiazhuang  | 0.6199| 0.8381| 1.1213|
| Chengde       | 0.2469| 0.3388| 0.4532|
| Zhangjiakou   | 0.2827| 0.3869| 0.5177|
| Qinhuangdao   | 0.5069| 0.4731| 0.6158|
| Tangshan      | 0.6202| 0.8171| 0.9972|
| Langfang      | 0.6044| 0.7350| 0.9194|
| Baoding       | 0.5474| 0.7413| 0.9918|
| Cangzhou      | 0.5685| 0.7454| 1.1208|
| Hengshui      | 0.3295| 0.4085| 0.6355|
| Xingtai       | 0.5427| 0.6734| 0.9834|
| Handan        | 0.5505| 0.8378| 1.0292|
| Anyang        | 0.2987| 0.4750| 0.6329|
| Shenyang      | 0.3468| 0.4603| 0.6019|
| Huhhot        | 0.3372| 0.4499| 0.5465|
| Taiyuan       | 0.3687| 0.5025| 0.6722|
| Zhengzhou     | 0.3482| 0.6872| 0.9009|
| Jinan         | 0.4965| 0.7693| 1.0931|

3.2 Model building

In order to test the impact of intercity linkages on TFP, the following empirical analysis model is established, as shown in formula (6):
$TPF = \theta_0 + \alpha X + \sum_{j=0}^n \theta_{j+1} X_j + \mu_i + \epsilon$ (6)

In the formula, $X$ is the core explanatory variable, i.e. intercity connection; $X_j$ is the control variable. As the factors affecting the economic efficiency of urban agglomeration are not limited to explanatory variables, we need to separate these factors and highlight the role of explanatory variables. The population scale, openness, public service, industrial structure and infrastructure of the city are selected as the control factors.

3.3 Empirical results

3.3.1 Descriptive analysis

Table 6. Descriptive statistics of variables

| Variable          | mean value | standard deviation | minimum value | maximum value |
|-------------------|------------|--------------------|---------------|---------------|
| TFP               | 0.6840     | 0.3137             | 0.2469        | 1.9064        |
| Degree centrality | 2.0840     | 1.3706             | 0.0000        | 4.2405        |
| Closeness centrality | 2.7239     | 1.5670             | 0.0000        | 4.3832        |
| Betweenness centrality | 0.8239     | 1.2888             | 0.0000        | 4.0184        |
| Population scale  | 6.4260     | 0.4756             | 5.3974        | 7.2160        |
| Openness          | 20.437     | 42.0052            | 0.1110        | 243.2900      |
| Public service    | 0.1411     | 0.0491             | 0.0686        | 0.3038        |
| Industrial structure | 0.4469     | 0.1244             | 0.2577        | 0.8023        |
| Infrastructure    | 13.504     | 4.3074             | 6.7700        | 22.7900       |

3.3.2 Regression results

Based on the panel data of 2007, 2013 and 2017, the empirical results in Table 7 are obtained, and the equation is significant as a whole. The degree centrality of the empirical results in Table 7 are obtained, and the equation indicates that the central position of the urban agglomeration network promotes the TFP of the city; meanwhile, the population size, openness and industrial structure of the control variables all play a role in promoting. As the core explanatory variable, the closeness centrality and betweenness centrality are not significant in this study.

Table 7. Estimation of the impact of intercity linkages on TFP

| Variable          | Coefficient | Standard error | T statistic |
|-------------------|-------------|----------------|-------------|
| Constant term     | -0.846**    | 0.308          | -2.751      |
| Degree centrality | 0.137**     | 0.039          | 3.484       |
| Closeness centrality | -0.016      | 0.031          | -0.493      |
| Betweenness centrality | 0.030      | 0.019          | 1.568       |
| Population scale  | 0.159**     | 0.043          | 3.718       |
| Public service    | -0.438      | 0.391          | -1.12       |
| Industrial structure | 0.689**    | 0.15           | 4.597       |
| Infrastructure    | -0.002      | 0.004          | -0.525      |
| R²                | 0.897       | 0.080          |             |
| F-statistic       | 52.335      | Prob(F-statistic) | 0.000       |

Note: *** represents significance level < 0.01, ** represents significance level < 0.05, * represents significance level < 0.1.

To sum up, the status of cities in the urban agglomeration network does have an impact on their TFP, that is, the connection between cities has a positive impact on urban development. How should cities improve their ability and status of connect with the outside world? This needs further study. Therefore, this paper further explores the impact mechanism of urban agglomeration network.

3.4 Model building

3.4.1 Analysis of influencing factors

Some factors, such as geographical location, traffic conditions and development level, will have an impact on the connection network. Most of the existing studies have studied the impact of traffic, investment and consumption, industrial structure, economic globalization on the formation of the connection network of the urban agglomeration13. The direct impact of traffic accessibility and geographical proximity on the connection network is obvious, and has been studied and confirmed by many scholars. Therefore, this paper focuses on the impact of the differences in labor, investment, industrial structure and economic openness on the network structure.

Table 8. Variable matrix description

| Variable          | Symbol | Explain |
|-------------------|--------|---------|
| Labor scale differences | L(i,j) | Based on the data of urban labor quantity, the matrix of labor difference between cities is constructed. |
| Labor wage difference | S(i,j) | Select the base city and calculate the difference of wage ratio between the two cities to construct the wage level difference matrix. |
| Investment difference | I(i,j) | Based on the data of urban fixed asset investment, the difference of fixed asset investment proportion in each city is calculated to construct the investment difference matrix. |
| Industrial structure difference | Ind(i,j), Inds(i,j), Indt(i,j) | The difference matrix of industrial structure is constructed by calculating the ratio of the secondary and tertiary industries to the regional GDP between the two cities. In order to study accurately, the difference matrix of the second industry and the third industry will be constructed |
4 Conclusions and recommendations

The main conclusions are as follows: (1) The connection between cities has a positive effect on TFP in urban agglomeration. (2) Besides geographical space and transportation factors, through the QAP analysis, it is found that the differences in labor market scale, industrial structure and economic openness also contribute greatly to economic ties.

Policy suggestions: (1) Enhance the openness of the city, actively connect with the outside world to seek development opportunities, and inject power into invigorating the economy. (2) Promote the establishment of an integrated labor market. (3) Promote industrial development in low-lying areas to achieve industrial upgrading, and guide the industrial structure and the advantages of technical personnel to reach the surrounding areas.

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Reference

1. B. Johansson, J. Quigley, Papers in Regional Science (2004)
2. R. Capello, Urban Studies (2000)
3. L. Suwala, Journal of International Business Studies (2013)
4. Z. Neal, New York: Routledge (2013)
5. P. McCann, Z. Acs, Regional Studies (2011)
6. W. Zhao, L. Jing, Finance & Economics (2015)
7. J. Li, S. Chen, G. Wan, etc, Economic Research Journal (2014)
8. H. Miao, H. Zhou, Industrial Economic Review (2018)
9. J. Liu, Shanghai: Shanghai People's Publishing House (SPPH) (2014)
10. C. Zhu, H. Yue, P. Shi, The Journal of Quantitative & Technical Economics (2011)
11. H. Shan, The Journal of Quantitative & Technical Economics (2008)
12. X. Sun, Z. Wang, G. Zhang, Journal of Zhongnan University of Economics and Law (2017)
13. Y. Zhong, X. Feng, Y. Wen, Scientia Geographica Sinica (2016)