Industrial Linkage Network Characteristics and Co-agglomeration of Urban Agglomerations in China

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Abstract. Based on the input-output table data of 17 urban agglomerations in China in 2012,2015 and 2017, this paper uses the two-way fixed effect model to analyze the impact of industrial correlation network density, clustering coefficient and average path length of producer services and manufacturing on industrial co-agglomeration. It is found that there are obvious small-world characteristics in China's producer services and manufacturing industry correlation networks. The network density and clustering coefficient of the industrial network will negatively affect the level of industrial co-agglomeration, while the average path length will positively affect the level of industrial co-agglomeration. Sub-regional sample regression found that only the eastern and central urban agglomeration effects exist. The empirical results of this paper are of great significance to promote the industrial development of urban agglomerations.

Keywords: Urban agglomeration · industrial linkage network · producer services · manufacturing · industrial co-agglomeration

1 Introduction

Speeding up the construction of a new development pattern with domestic major circulation as the main body and domestic and international double circulation promoting each other is China's "14th Five-Year Plan" and major economic strategy in the future. One of the development priorities of "internal circulation" is to form a whole industrial organization and an internal mechanism for industrial development, which needs to condense the industrial chains in the upper, middle and lower reaches on a larger spatial scale. Different from the phenomenon of agglomeration of individual industries in a single region, the coordinated agglomeration of industries in urban agglomeration emphasizes the spatial dependence, distribution and connection of cross-industries. The dual characteristics of industry and space and the interaction with the spatial infrastructure are of key significance to the search for the economic space in the reasonable space and the industrial power point1.

Although the existing research has incorporated spatial factors into the industrial analysis framework, the research on the spatial co-agglomeration of producer services and manufacturing is still in its infancy. Few scholars take the spatial agglomeration

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between the two as the research object2. Due to the data of China's input-output table, the existing industrial linkage research only takes a single city or province as the research object, and lacks research of urban agglomeration3. Its relationship with spatial industrial agglomeration is also concentrated in the descriptive statistics of phenomena, and lacks the empirical level, especially the panel data empirical test of the combination of industry and city. Fewer studies have incorporated the network characteristics of industrial linkages into the study of industrial spatial agglomeration.

Compared with the existing literature, the contribution of this paper is mainly reflected in: (1) using the social network analysis method to calculate the characteristics of the industrial linkage network of each urban agglomeration. (2) using panel data to empirically test the impact of the network linkage characteristics of producer services and manufacturing on co-agglomeration.

2 Empirical Design

2.1 Estimating Model

In order to test the hypothesis 1 of the theoretical model, this paper first constructs a benchmark model of the impact of urban transportation infrastructure on industrial co-agglomeration.

$$La_{it} = \beta_0 + \beta_1 DE_{i,t} + \delta X_{it} + \lambda_t + u_i + \varepsilon_{it} \tag{1}$$

$$La_{it} = \beta_0 + \beta_1 CC_{i,t} + \delta X_{it} + \lambda_t + u_i + \varepsilon_{it} \tag{2}$$

$$La_{it} = \beta_0 + \beta_1 LA_{i,t} + \delta X_{it} + \lambda_t + u_i + \varepsilon_{it} \tag{3}$$

The left of the equation is the explained variable producer services and manufacturing co-agglomeration level. DE, CC and LA on the right side of the equation are the core explanatory variables, which represent the network density, clustering coefficient and average path length of industrial linkage respectively. Xit is a series of control variables that affect the co-agglomeration of producer services and manufacturing.The model includes individual effect ui and time effect λt.

2.2 Variable Selection and Data Description

Explained variable (*La*): producer services and manufacturing co-agglomeration. This paper mainly focuses on the influence of industry and regional size, and uses location entropy as a measure of producer service agglomeration and manufacturing agglomeration. The specific calculation methods for comprehensively reflecting the level of collaborative agglomeration are as follows:

$$L_{ij}=(\frac{X_{ij}}{Y_j})/(\frac{X_i}{Y}) \tag{4}$$

Lij represents the agglomeration index of industry i in region j, Xij represents the number of employees in industry i in region j, Yj represents the total number of employees in region j, Xi represents the number of employees in industry i in the whole country, and Y represents the total number of employees in the whole country.

At the same time, this paper draws on the methods of Chen (2013) to improve the EG index and Zhang et al.5to construct a co-agglomeration index as shown in formula (5).

$$La=\left(1-\frac{|L_{manu}-L_{pro}|}{L_{manu}+L_{pro}}\right)+|L_{manu}+L_{pro}| \tag{5}$$

Explanatory variables: producer services and manufacturing industry network correlation characteristics. Using the inter-city input-output table of 2012,2015 and 2017, the industrial nodes of the internal cities of each urban agglomeration and the direct consumption coefficient between the two industries are used as edges to construct an industrial correlation network. Gephi software was used to visualize the industrial linkage network of urban agglomerations, and the indicators of the overall characteristics of the network were calculated. The main indicators and calculation methods are shown in Table 1.

The same color table in industrial linkage network diagrams (a) is the same city, which is used to compare the differences in industrial linkages between different cities in the urban agglomeration. The black and gray nodes of Figure (b) represent producer services and manufacturing respectively to measure the differences in inter-industry linkages. At the same time, because there are many edges between the industries of the urban agglomeration, in order to visualize the same filtering settings for each urban agglomeration, the Fruchterman Reigold layout is used.

Figure 1 reports the input and output of intra-city and inter-city industries in the Yangtze River Delta urban agglomeration. On the whole, the industrial correlation is significant. The network density and clustering coefficient are about 0.7, and the average path length is about 1.2 and stable. In terms of regions, industrial linkages are stronger within cities and weaker between cities, but as time evolves, inter-city linkages gradually

Table 1. Industrial network correlation overall characteristic index

Index	Calculation formula	Description	Connotation
DE	$T/n(n-1)$	T is the actual number of edges in the network, and $n\ (n-1)$ is the maximum possible number of edges in the directed graph.	The closeness of industrial network connection
CC	$\frac{1}{n}\sum_{i=1}^{n}\frac{2E_i}{k_i(k_i-1)}$	E_i is the actual number of edges between k neighbor nodes of node i.	The overall agglomeration degree of the network
LA	$\frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}d_{ij}$	d_{ij} is the shortest path between i and j.	The overall industrial chain depth level of the industrial network

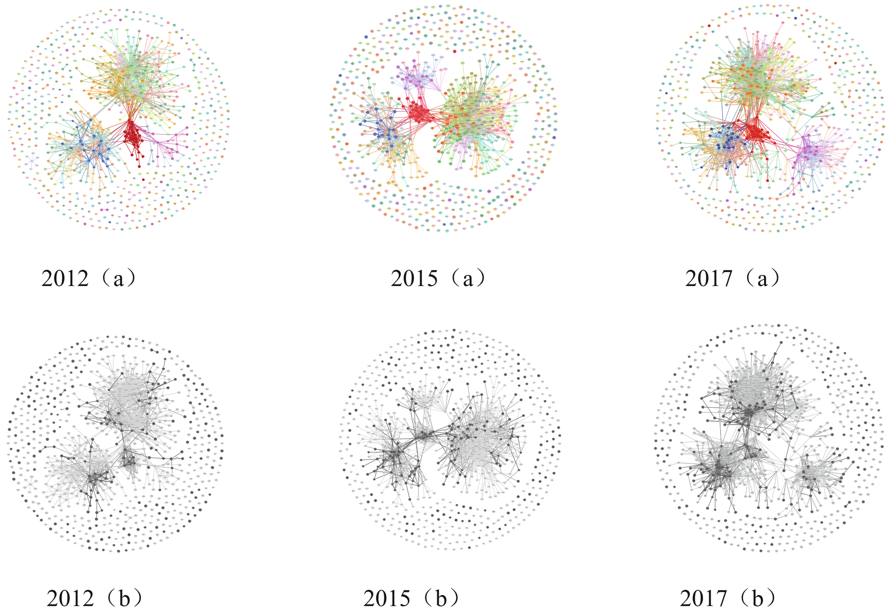

Fig. 1. Industrial input-output correlation network of Yangtze River Delta urban agglomeration

strengthen. In 2012, the industrial connection between Shanghai and Hangzhou in the Yangtze River Delta urban agglomeration was very close, but the connection with other cities was not strong. After 2017, Shanghai and Hangzhou, Jiaxing and Shaoxing have formed close connections. Some cities in Hefei have not yet formed close ties with other major cities in the Yangtze River Delta due to their late inclusion in the Yangtze River Delta urban agglomeration.

Control variables: *Tran*: traffic infrastructure construction level. The urban road area is divided by the value of the urban area. *Inform*:the level of urban informatization. The total amount of telecommunication services is measured and logarithmically processed. *Lngdp*: Economic development level. Taking 2012 as the base period, and through the CPI index, the per capita regional GDP affected by the price is proposed and logarithmically processed. *Fdi*: The level of opening to the outside world, using the proportion of the actual utilization of foreign capital in the city's GDP and standardizing the data. *Hr*: the level of urban human capital. The number of students in colleges and universities per 10,000 people is adopted and standardized. *Gov*: the level of government intervention. It is measured by the proportion of urban government general budget expenditure to GDP. *Rd*: innovation level. The scientific expenditure in the general budget expenditure is measured and logarithmically processed. The above data are aggregated to the urban agglomeration level using urban data.

2.3 Data Description

The data of the above urban agglomerations are mainly derived from the 'China Urban Statistical Yearbook', the balanced panel data of 163 cities in 17 urban agglomerations

Table 2. Descriptive statistics of variables

Var	Obv	Mean	std	Min	Max
La	51	2.93	0.756	1.967	5.92
DE	51	0.62	0.157	0.348	0.966
CC	51	0.722	0.111	0.362	0.966
LA	51	1.306	0.144	1.029	1.657
Tran	51	0.098	0.756	0.355	3.262
Inform	51	3.79	0.575	2.509	5.048
Lngdp	51	11.09	0.348	10.32	11.72
Gov	51	0.164	0.043	0.056	0.246
Rd	51	11.09	0.995	9.369	13.6
Fdi	51	0.003	0.002	0	.01
Hr	51	308.1	101	135.5	627.3

were finally obtained. The input-output table data at the city level comes from the Chinese carbon accounting database CEADS, Zheng et al.4 based on the entropy model, a framework for the preparation of an urban-scale input-output model was constructed, and a multi-regional input-output table of China's urban scale in 2012, 2015 and 2017 was compiled. The descriptive statistics of the main variables are shown in Table 2.

3 The Economic Estimates and Implications

3.1 Basic Regression Results

Table 3 reports the empirical results of the impact of the overall characteristics of the industrial network of urban agglomerations on industrial co-agglomeration. Column (1) shows that the coefficient of DE is significantly negative in both equations after adding individual fixed effect, year fixed effect and control variables, indicating that the network density in industrial network characteristics will inhibit the overall industrial co-agglomeration level of urban agglomeration. The network density in the industrial network characteristics will also inhibit the overall industrial co-agglomeration level of the urban agglomeration. The coefficient of LA is significantly positive in both equations, indicating that the average path length of urban agglomeration industrial network has a significant role in promoting the overall industrial agglomeration level of urban agglomeration.

3.2 Heterogeneity Test

According to the geographical location of the urban agglomeration, the urban agglomeration is divided into three regions, and the dummy variable is added on the basis of Eqs. (1)–(3). The sub-sample regression results show that only the industrial network DE,

Table 3. Basic regression results

		(1)	(2)	(3)
DE		−0.831** (0.16)		
CC			−1.672** (0.73)	
LA				0.949** (0.50)
Control variables		YES	YES	YES
Code FE		YES	YES	YES
Year FE		YES	YES	YES
R^2		0.720	0.795	0.706
N		51	51	51

Note: Standard errors are given in parentheses. ***, ** and * denote statistical significance at p = 0.01, 0.05 and 0.1, respectively

Table 4. Regression robustness test

	(1)	(2)	(3)
DE	−0.421** (0.20)		
CC		−1.004** (0.45)	
LA			0.264** (0.12)
Control variables	YES	YES	YES
Code FE	YES	YES	YES
Year FE	YES	YES	YES
R^2	0.951	0.924	0.917
N	51	51	51

CC and LA are significant in the samples of the eastern and central urban agglomerations. This is mainly because the industrial network of producer services and manufacturing in the west is generally sparse and has not yet formed a complete industrial association. Comparing the coefficients of the eastern, central and western regions, it is found that the coefficients of urban agglomerations in the eastern region are significantly larger than those in the central region, whether DE, CC or LA, which further indicates that the effect of industrial network is more inclined to resource-intensive areas, and the role of industrial chain needs to rely on high-density industrial links.

4 Robustness Test

In order to further examine the robustness of the regression results and replace the measurement method of the explained variables, which in the Table 4. The C(r) co-agglomeration index proposed by Devereux on the basis of Ellision and Glaeser's research is used for measurement.we can seen that the network density and clustering coefficient of the urban agglomeration industrial network are significantly negative, while the estimated coefficient of the average path length is always positive, which is consistent with the previous estimation results.

5 Conclusions

The industrial association network of the head city group has obvious small world characteristics, that is, the network density and clustering coefficient are large, and the average path length is short. The main reason is that the role of the market in the allocation of resources has been continuously strengthened, and the scale effect and specialization of the industry have been significantly improved. However, the 'economies of scope' formed by over-reliance on the scale of low-end manufacturing has resulted in short-term profitability, long-term damage, lack of deep linkage of the industrial chain and low-end locking.

The network density and clustering coefficient will inhibit the level of industrial co-agglomeration, while the average path length will positively affect the level of industrial co-agglomeration. The sub-sample regression results show that only the industrial network characteristics in the eastern and central regions have a significant impact on industrial co-agglomeration.

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