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Interprovincial Trade Evolutionary Relationships from a Complex Network Perspective

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Abstract

In this paper, the GDP and geographic distance data of each province for four years in 2007, 2012, 2017 and 2022 are collected, and under the premise that there is no specific interprovincial trade value, the gravitational model is used to estimate the interprovincial trade flow data under different years, and the fully connected network is plotted by using it as the weight and each province as the node, and then the node strength of the four networks using the method of complex network analysis, the weighted close centrality, and weight entropy of the three major indexes are calculated separately to analyze their similarities and differences, and the spectral clustering algorithm is used to show the node clustering of each network, compare their differences, and analyze from them the changes in interprovincial trade relations under the development of the times.

Keywords

Complex Networks; Gravity Modeling; Interprovincial Trade.

1. Introduction

Interprovincial trade in goods and services is of great significance in promoting the economic development of inland provinces. The study of inter-provincial trade helps to understand the industrial division of labor and collaboration among provinces and to explore the competitive advantages and disadvantages of each province's industry.

At present, the analysis of inter-provincial trade in China can be roughly divided into three categories. One category is the analysis of the structure and attributes of the trade situation itself. Li Ziruo et al [1] studied the interprovincial trade barriers and trade costs; Peng Gang et al [2] analyzed the topological characteristics and evolution of the interprovincial trade network. The second category is to study the impact of interprovincial trade on other areas. Chen Lin et al [3] studied the impact of domestic and foreign trade on the environment in the context of the double cycle; Cong Jianhui et al. demonstrated the impact of interprovincial trade on carbon dioxide emissions [4]. The third category analyzes the impact of other factors on the development of interprovincial trade. Zhang Penglong et al [5] analyzed how population mobility affects interprovincial trade through preference differences; Li Hongbing et al [6] analyzed the impact of digital economy on interprovincial trade.

This paper, on the other hand, utilizes the complex network analysis method to estimate the trade value from the interprovincial trade itself, using the data of each province for the four years of 2007, 2012, 2017, and 2022, and explores the similarities and differences of the trade network in each period and discusses its evolutionary relationship.

ISSN: 2688-8645

2. Gravitational Modeling

There is no explicit inter-provincial trade data available in the public data, so this paper uses the gravity model to collect relevant data from the China Statistical Yearbook and Baidu Maps to estimate the closeness of trade links among provinces.

Gravitational models are often used in economics and physics. For the purpose of this paper, the gravity model can be used to predict the trade flows between two provinces, i.e., the province with a larger economic volume tends to have more trade flows, while the trade between provinces that are farther away has a higher cost and a smaller trade volume, with the following specific formulas[7].

$$F_{ij} = k\frac{G_i * G_j}{{D_{ij}}^{\theta}}$$

Where, F_{ij} denotes the trade flow between two provinces i and j, G is GDP, D_{ij} means the distance between the two provinces, k is the gravitational constant, usually taken as 1, and θ is the distance friction coefficient, usually taken as 2.

The trade flows between some of the provinces were calculated and are shown in table 1.

Table 1. Results of partial estimation of trade flows

	2022	2017	2012	2007
Beijing-Tianjin	36215.02	27727.31	12300.70	2520.49
Beijing-Hebei	20906.26	11300.14	5634.21	1520.53
Beijing-Shanxi	4467.70	1821.513	906.80	224.54
Beijing-Inner Mongolia	4095.03	1916.24	1206.58	242.10

Considering the length of the article, only the changes in trade flows between individual provinces in the four years of 2022, 2017, 2012, and 2007 are shown, and only from some of the data, it can be seen that the value of interprovincial trade has been steadily increasing in all cases since 2007, and the interprovincial trade relationship is getting closer, and the value of each province's GDP has increased significantly, and the form of the domestic economy has become more and more clear.

3. Network Construction and Analysis

After obtaining the inter-provincial trade flow values, this paper takes each province and municipality directly under the central government as a node and uses the flow values as weights to construct a fully connected trade network. Considering the readability of the image, the flow value is normalized and multiplied by 100 to constrain it between 0 and 100 as the actual weight. Figure 1 illustrates the interprovincial trade for each of the four years.

According to the information in the chart, it can be found that when 2007, the trade flow between the four provinces of Shanghai, Jiangsu, Zhejiang and Anhui was the highest, and the trade links between Beijing and Tianjin, Shandong, Hebei and Shandong and Hebei ranked at the top of the list; and by 2012, the trade between Jiangsu and Anhui was the closest, followed by Zhejiang and Shanghai, Jiangsu, and compared to 2007, the trade between Shanxi and other provinces has significantly improved; in 2017, the gap between Anhui, Jiangsu, Zhejiang, and Shanghai and other provinces began to show, such as Henan and Hunan began to improve the form of the economy; in 2022, the leading position of the four provinces is even more obvious, the economy of Sichuan began to develop, and the trade between Beijing and Tianjin began to

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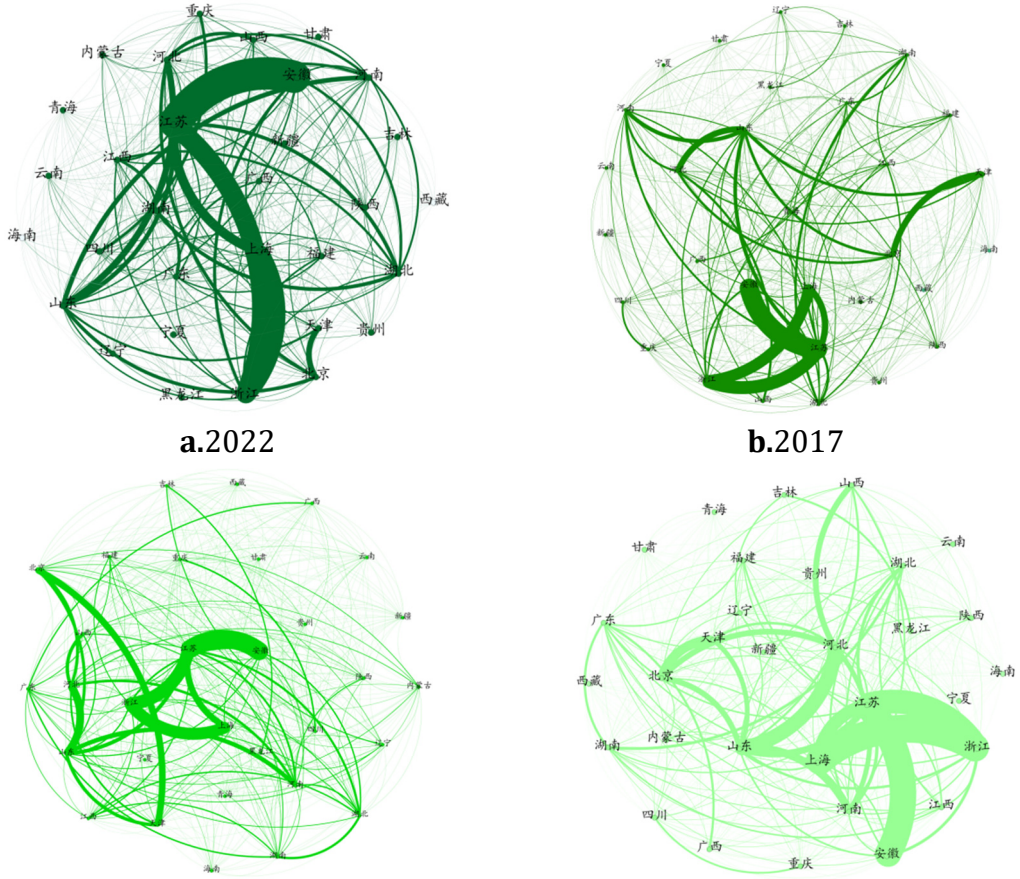
converge with the other provinces, but more and more provinces began to close economic exchanges, and the links between the places increased significantly.



a.2022 **b.**2017

c.2012 **d.**2007

Figure 1. Network map of interprovincial trade flows over four years

In order to better understand the inter-provincial trade at different times, this paper will analyze the following indicators step by step.

3.1. Comparison of Node Strength

For the fully connected weighted network, the node weighting degree can better reflect the importance of the node in the network compared to the degree, the larger the weight, the larger the trade flow between the province and other provinces, the larger the node weighting degree, the larger the trade flow and the larger the trade flow between the province and other provinces, i.e., the closer the interprovincial relationship it has.

Table 2 shows the weighted degree of the first and last nodes in the interprovincial trade network under different years.

Table 2. Weighting degree of some nodes

	2022	2017	2012	2007
Jiangsu	257.99	282.57	291.92	317.16
Zhejiang	158.99	173.87	188.02	245.18
Xinjiang	0.96	0.99	1.18	1.21
Tibet	0.09	0.10	0.09	0.10

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The analysis shows that both the provinces with the highest and the lowest weighting degree have the largest node weighting degree in 2007 and the smallest node weighting degree in 2022. Considering that the weighting value of the network is the result of normalization, it can be concluded that, in 2007, the inter-provincial trade situation in the country was extremely different, and with the continuous development of the domestic economy, the trade situation between all the provinces began to gradually improve, and the mutual The gap began to narrow, which reflects the good development momentum of China's economy.

3.2. Weighted Close Centrality

Weighted centrality [8] is related to the weight of the edge, for the meaning of the data in this paper, the higher the weight of the edge, proving that the relationship between the nodes is more intense, that is, the smaller the weighted centrality, the more it shows that the province is located in the center of the inter-provincial trade network.

As with node strength, this section still lists indicators for some provinces.

Table 3. Weighted tight centrality of some nodes

	2022	2017	2012	2007
Hainan	318.98	310.38	341.45	314.84
Jilin	311.51	267.32	278.32	259.11
Sichuan	84.38	86.59	99.01	96.49
Guangdong	79.27	77.44	89.72	74.23

The two provinces of Jilin and Sichuan in Table 3 show different trade development trends, and in general, the weighted centrality of Jilin is getting bigger and bigger with the development of the society, indicating that the province is gradually becoming the center of inter-provincial trade, while the indicator value of Sichuan is getting smaller and smaller, indicating that the province attaches importance to the development of the economy and is gradually improving the trade with other provinces, so as to make itself more and more towards the center of the network and occupy more and more important positions in the trade relations to occupy an increasingly important position.

As for the two provinces of Hainan and Guangdong, the value of their weighted close centrality is not much different from the initial one, and keeping the data stable under the premise of decreasing inter-provincial trade gap can also indicate that they are in stable development.

3.3. Weight Entropy

Weight entropy is the uniformity or centralization of the network connection, is used to measure the difference between the edge weights in the network of indicators, applicable to the four network nodes in this paper, even the same edges and different weights, is conducive to showing the differences in the network under different years.

Table 4. Entropy of network weights in different years

	2022	**2017**	**2012**	**2007**
weight entropy	**4.24**	**4.29**	**4.35**	**4.22**

The weight entropy of the interprovincial trade network is calculated to be 4.24 in 2022, 4.29 in 2017, with a maximum of 4.35 in 2012 and a minimum of 4.22 in 2007, indicating that the gap in interprovincial trade was the smallest in 2012 compared to other years. Despite the differences in the values of the network indicators in different years, overall, the weight gap in

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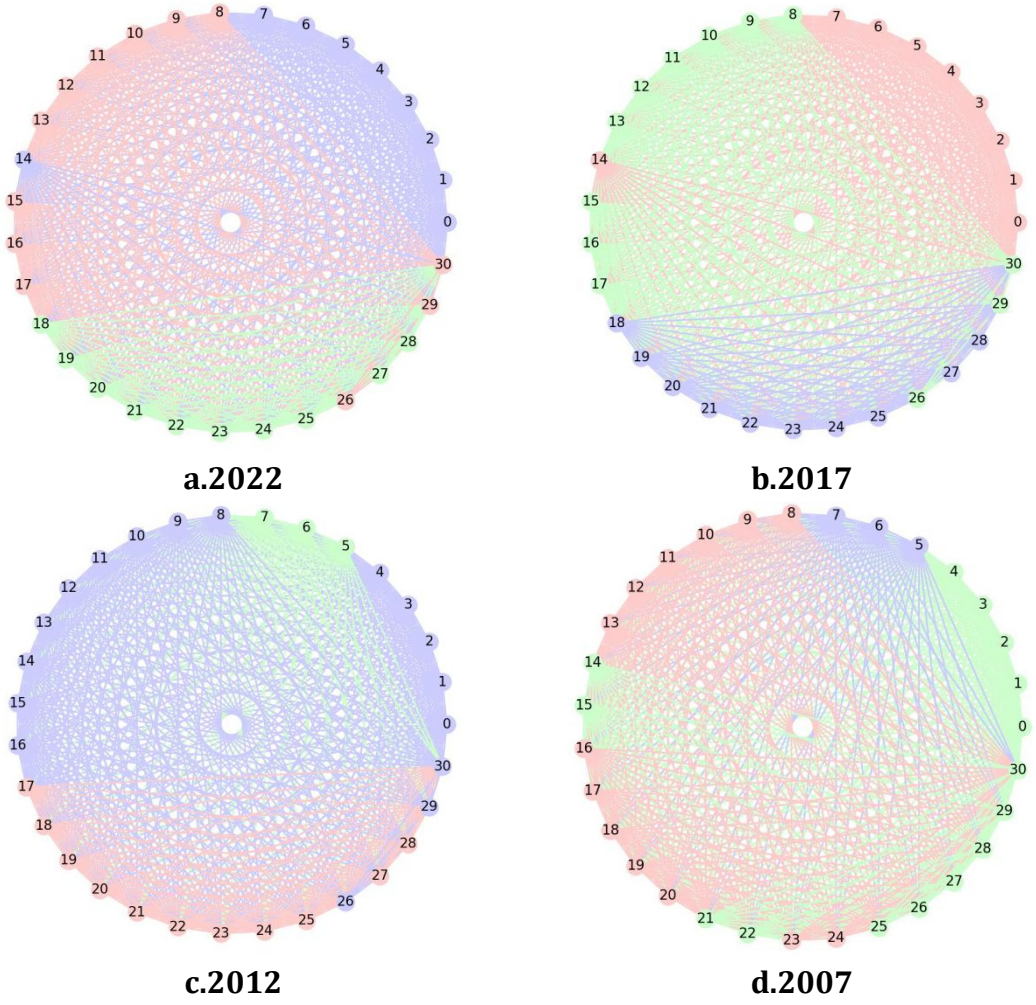
the network is still large, indicating that there is a situation in the network where the link between two provinces is far more important than the other two provinces.

3.4. Spectral Clustering

Spectral clustering [9] is a clustering method based on graph theory, which can well show the connection between different provinces under different years. Provinces located in the same category prove that their trade flows are relatively close, while provinces located in different categories have less trade flows between them.



a.2022 **b.2017**

c.2012 **d.2007**

Figure 2. Network clustering diagram

From the analysis in Figure 2, it is found that the classification of 2017 and 2022 is consistent, and both can be divided into three categories nearly evenly; the classification of 2012 and 2007 is not much different, and both Liaoning, Jilin and Heilongjiang provinces form a category of their own, but in 2007, Beijing, Tianjin, Hebei, Shaanxi, Inner Mongolia and Shandong, Henan, Chongqing, Sichuan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang into one category and the others into another, while in 2012 it is with Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Shaanxi, Ningxia and Xinjiang into one category, and the gap between them indicates that Shanghai and other places strengthened their trade with Beijing and other places in 2012. The network clustering diagram clearly reflects the change of trade relations among provinces under the development of the times.

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