The regional economic spatial pattern of Northeast China and its economic integration trend based on network perspective

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Abstract. Based on the modified gravity model and social network analysis method, the paper constructed the economic linkage intensity matrix of 34 prefecture-level cities of Northeast China and analyzed the density and structure of urban linkage networks. The results show that at present, the urban linkage network in the Northeast region is getting closer, and the radiation role of core cities is gradually increasing. However, the degree of regional integration in Northeast China is not high, and some remote cities are still semi-isolated from the network.

1 Introduction

Urban network refers to a networked group of cities of different scales and functions that are closely connected in terms of resources, industries, information, and transportation. The closeness degree and spatial structure of urban networks have become important indicators in measuring the social and economic development of a region.

The central place theory proposed by Christal laid the foundation for the study on spatial linkages of urban agglomerations[1]. After World War II, a large scale of urban group emerged, which lead to the formation of foreign scholars' ideas on the study of urban systems. In the 1990s, with the increasing development of transportation and communication, the relationship between cities became more complex. Scholars began to further explore inter-city economic linkage networks from new perspectives, such as transportation networks [2], air flows [3], and logistics [4].

In recent years, domestic scholars have mainly focused on provincial areas and more developed city clusters. They implemented their research based on gravity models [5], affiliation models [6], and urban flow intensity models [7] to analyze urban accessibility and urban cluster economic linkage patterns.

At present, some developed city clusters in coastal areas have formed a relatively mature city network system, while the economic development of northeast China still faces many problems. The paper takes into account various transportation modes, time cost, and monetary cost between the two cities to modify the traditional gravitational model and constructs a matrix of economic linkage intensity of northeast China. Subsequently, the paper analyzes the density and structure of economic linkage network based on social network analysis. On this basis, policy recommendations are proposed to strengthen the spatial linkages of Northeast cities.

2 Research Methodology and Data Sources

2.1 Modified gravitational model

The gravitation model is a common measure of economic link intensity between cities, The strength of economic ties between cities is calculated as follows

$$F_{ab} = k_{ab}(M_a M_b / D_{ab}^2)$$
$$k_{ab} = M_a / (M_a + M_b) \qquad (1)$$

Where F_{ab} is the gravitational force of city a on city b, k_{ab} is the gravitational coefficient of city a on city b, M_a and M_b are the combined masses of city a and city b, respectively, and D_{ab} is the distance from city a to city b.

In measuring the comprehensive quality of cities, We select 18 indicators from four aspects to construct a comprehensive quality evaluation system f based on the principal component analysis.

In terms of measuring the distance between two cities, we refer to Sun Jing's viewpoint [8], combining time distance and monetary distance to calculate economic distance. The "time distance" refers to the actual time required to travel between cities by various modes of transportation; the "monetary distance" refers to the actual price required to travel between cities by various modes of transportation. Subsequently, we assign different weights to various modes of transportation, which can help enhance fitting degree between distance variable and reality.

$$D_{ab} = \sum_{i=1}^{n} w_i T_{iab} R_{iab} \qquad (2)$$

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where D_{ab} is the economic distance between two cities, w_i is the weight of the ith transportation mode, T_{iab} is the time distance from the city a to city b for the ith transportation mode, and R_{iab} the monetary distance from the city a to city b for the ith transportation mode.

2.2. Social network analysis

The social network analysis method is the mainstream method for analyzing interactions among nodes. Based on the economic linkage values calculated by the modified gravity model mentioned above, we construct the urban spatial linkage matrix, import it into UCINET to analyze the network density, network centrality, and network cohesion subgroups.

2.3. Study area and data sources

This paper focuses on the 34 prefecture-level cities of

northeast area and selects the relevant data in 2010, 2014, and 2018 for research. The data for measuring the economic quality of cities are obtained from the *Liaoning Provincial Statistical Yearbook*, *Heilongjiang Provincial Statistical Yearbook*, *Jilin Provincial Statistical Yearbook* and *China City Statistical Yearbook* in 2010, 2014, and 2018. The data for measuring economic distance are obtained from the official website of 12306 and Ctrip.com.

3 Social network analysis

3.1 Network density analysis

Importing the calculated spatial linkage matrix into NetDraw to draw the linkage network structure (Figure 1), we can find that the city linkage network is gradually dense, which indicates the increasing economic linkage among cities in Northeast China.
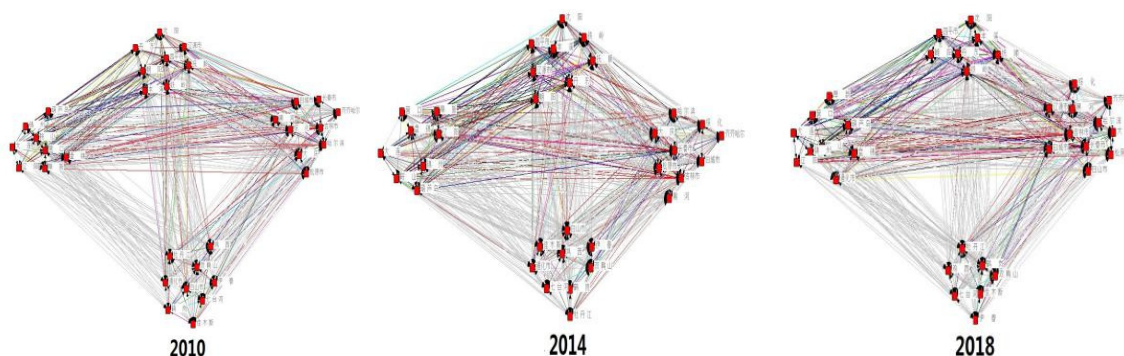

Figure 1 Structure of the economic linkage network of cities in the Northeast region

3.2 Centrality analysis

Degree centrality measures the central position of a node in the network. For a directed network, degree centrality

is classified into in-degree centrality and out-degree centrality. In-degree centrality can reflect the degree of influence of the node by other nodes, and out-degree centrality can reflect the degree of influence of the node on other nodes.(Table 1)

Table 1 degree centrality of northeast economic connection network in 2010, 2014 and 2018

city	2010		2014		2018		city	2010		2014		2018	
	od	id	od	id	od	id		od	id	od	id	od	id
Harbin	26	27	26	27	31	27	Tonghua	18	16	18	16	18	16
Changchun	27	27	27	27	27	27	Fuxin	18	16	18	16	17	17
Jilin	26	25	26	25	26	25	Dalian	17	19	17	19	17	19
Shenyang	26	24	26	24	26	24	Daqing	13	14	13	14	16	14
Sipiong	25	25	25	25	25	25	Suihua	16	16	16	16	16	16
Tieling	24	25	24	25	24	25	Baicheng	14	17	14	17	14	16
Liaoyuan	22	21	22	21	22	21	Chaoyang	14	18	14	18	14	18
Anshan	21	22	21	22	21	22	Qiqihaer	12	12	12	12	12	12
Liaoyang	21	21	21	21	21	22	Mudanjiang	12	11	12	11	12	11
Benxi	20	21	20	21	20	21	Jiamusi	11	12	11	12	11	12
Jinzhou	20	20	20	20	20	21	Baishan	10	8	10	8	10	8
Fushun	19	19	19	19	19	19	Hegang	8	7	8	7	8	7
Songyuan	17	14	17	14	18	14	Shuangyashan	7	7	7	7	7	7
Panjin	18	18	18	18	18	19	Qitaihe	7	6	7	6	7	7
Yingkou	18	19	18	19	18	19	Jixi	5	6	5	6	5	6

| Dandong | 18 | 18 | 18 | 18 | 18 | 19 | Yichun | 5 | 5 | 5 | 5 | 5 | 6 |
| Huludao | 18 | 17 | 18 | 17 | 18 | 18 | Heihe | 1 | 1 | 1 | 1 | 1 | 2 |

From the out-degree centrality, We can conclude that Harbin, Changchun, and Shenyang have higher out-degrees, which indicate that the three provincial capitals have the strongest influence on other cities. The out-degree of Harbin has increased significantly in 2018, indicating the enhanced radiation capacity of Harbin. In addition, probably due to the convenient transportation and strong economic strength of Liaoning Province, the out-degree centrality of cities in Liaoning Province is at a high level. Jilin City, Siping City and Liaoyuan City have high out-degree centrality, while the other four cities of Jilin province are at a fair level. Some cities has almost no influence, which may be related to the location, climate, and traffic of these cities.

According to in-degree centrality, we can conclude that among the three provincial capitals, The centrality of Shenyang is relatively low. Dalian has a high economic comprehensive quality, but its centrality is in the middle, which is not quite consistent with reality, probably because we regarded the Northeast as a relatively closed region, while Dalian is geographically located at the edge of the Northeast and has a long economic distance from other cities.

3.3 Block model analysis

In order to further analyze the network structure, the overall network can be divided into several subgroups. We choose the CONCOR clustering method to analyze the city clusters with relatively close economic relations and explore the structure of economic integration of the three eastern provinces. It can be seen that the 34 prefecture-level cities in the eastern provinces can be divided into four cohesive subgroups.(Table 2)

Table 2 agglomeration subgroups of northeast economic connection network in 2010, 2014 and 2018

year	num	member
2010	1	Changhchun,Jilin,Suihua,Baicheng,Harbin,Daqing,Songyaun,Qiqihaer,Heihe
	2	Hegang,Tonghua,Jiamusi,Shuangyashan,Baishan,Yichun,Mudanjaing,Qitaihe,Jixi
	3	Liaoyuan,Siping,Lioayuan,Siping,Shenyang,Dandong,Benxi,Fushun,Chaoyang,Tieling
	4	Anshan,Dalian,Jizhou,Liaoyang,Panjin,Yingkou,Fuxin,Huludao
2014	1	Changhchun,Jilin,Suihua,Baicheng,Harbin,Daqing,Songyaun,Qiqihaer, Heihe
	2	Hegang,Tonghua,Jiamusi,Shuangyashan,Baishan,Yichun,Mudanjaing,Qitaihe,Jixi
	3	Liaoyuan,Siping,Lioayuan,Siping,Shenyang,Dandong,Benxi,Fushun,Chaoyang,Tieling
	4	Anshan,Dalian,Jizhou,Liaoyang,Panjin,Yingkou,Fuxin,Huludao
2018	1	Changhchun,Jilin,Suihua,Liaoyuan,Harbin,Baishan,Songyaun,Baicheng,Heihe,Qiqihaer,Daqing
	2	Shuangyashan, Qitaihe,Hegang,Yichun,Jiamusi,Jixi,Mudanjaing
	3	Shenyang,Siping,Benxi,Dandong,Chaoyang,Fushun,Tieling
	4	Anshan,Jinzhou,Dalian,Tonghua,Liaoyang,Panjin,Yingkou,Fuxin,Huludao

It can be seen that the members of agglomerate subgroups have not changed from 2010 to 2014. The first cohesive subgroup is formed around Changchun and Harbin, including two important urban agglomerations: Changji Economic Belt and the Hadazhi Industrial Corridor, which is the hub of economic development in the eastern provinces; the second cohesive subgroup consists of Tonghua, Baishan, and eastern cities of Heilongjiang Province. This subgroup contains several cities with less convenient transportation and weaker economic strength, which are less connected to other cities; the third subgroup is centered on Shenyang of Liaoning Province, and also contains Siping and Liaoyuan of Jilin Province, which is another pillar of the economic development of the eastern provinces; The fourth cohesive subgroup contains coastal cities such as Dalian and Huludao, which have convenient foreign trade, excellent industrial structure, and str ong comprehensive economic strength. Although Chaoyang should belong to the fourth subgroup from a geographical point of view, it is actually more closely connected with Shenyang, which may be related to the convenience of railroad transportation. In 2018, the members of each agglomerative subgroup changed significantly. Liaoyuan City and Baishan City join in the first cohesive subgroup, indicating that the radiation effect of the city network centered around Changchun and Harbin has increased; the second cohesive subgroup is still a less economically developed area in Heilongjiang Province; The members in the third cohesive subgroup have not changed, but it can be concluded that Siping City has established close ties with Liaoning Province; Tonghua joined in the fourth cohesive subgroup, which indicates that the completion of Tonghua International Inland Port in 2016 has greatly enhanced the degree of opening up of Jilin Province.

4 Conclusions and Policy Recommendations

4.1 Conclusion

Based on the above analysis, the following conclusions

can be drawn: The relatively weak economic strength of many cities and the unbalanced development of each region is one of the main obstacles to the integration of Northeast China. At present, Liaoning Province has has formed a certain close economic linkage network. Siping City is adjacent to Liaoning Province and has established close ties with it. There is still room to improve the radiation effect of the city cluster around Changchun and Harbin. Some remote cities of Heilongjiang Province are economically weak and are almost separated from the linkage network. the linkage network radiation with Harbin, Qiqihar, and Daqing as the core is not enough to drive some cities with backward economic development.

4.2 Policy recommendations

Firstly, it can be concluded that it is far from enough for the three eastern provinces to rely only on the three provincial capitals to support and drive the economic development of other cities. Therefore we should focus on giving full play to the advantages of the location, developing special industries and improving the quality of the city's economy. Secondly, It is urgent to improve the transportation networks of cities with more remote geographical locations, which can Reduce transportation costs and narrow the economic distance between cities.In addition, We should improve the radiation capacity of central cities and enhance the absorption capacity of small and medium-sized cities. It is suggested to create multi-level and multi-center city clusters and try to establish secondary economic centers.

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