The relationship between Liaoning urban agglomeration based on Gravity Model

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Abstract. This paper simulates the economic gravitation between 14 prefecture level cities of Liaoning province by gravity model, and achieves data visualization through ArcMap and Ucinet. It is concluded that the central city group of Liaoning is composed of Shenyang, Liaoyang, Benxi, Anshan, Fushun and Tieling. The southern city group of Liaoning is composed of Dalian, Yingkou, Panjin, Huludao and Jinzhou.

1 Introduction

Over the past decades, it has been manifested that urban agglomeration has become an important force in regional development. According to theoretical studies, the close economic links between urban agglomerations are the essential characteristics of urban agglomeration. Quantitative analysis of economic links is the basis for determining the scope of urban agglomerations. In this paper, a gravity model is established to reflect the spatial and economic interaction of cities based on the theory of city connection in regional economics. In the Chinese urban agglomerations, the central city group of Liaoning is a typical resource-based city group in Northeast China. Because Shenyang and Dalian are the leading cities in Liaoning, there is also a theory based on the dual core cities in central and southern Liaoning (the coastal area of southern Liaoning includes Dalian, Dandong, Yingkou and Panjin. The central Liaoning region includes Shenyang, Anshan, Fushun, Benxi and Liaoyang). Therefore, with the increasing role of the urban system in revitalizing the old industrial base in Northeast China, it is necessary to study the spatial economic structure and hierarchical structure of the city. We take Liaoning Province as an example to make an empirical analysis.

2 Related Work

Liaoning province, located in the south of northeast China, is the cradle of new China's industry. Liaoning province has 14 prefecture-level cities. There are two main views on the division of city clusters in Liaoning Province. The central city group of Liaoning refers to the central part of Liaoning, the core area of heavy industry in Northeast China, with Shenyang as the central city, including Anshan, Fushun, Benxi and Liaoyang, which are five large and medium-sized cities. It is also one of

the most densely populated metropolitan groups in China([1]). The second point is the dual core mode of Shenyang - Dalian, which was first proposed as a dual core system of regional tourism. Shenyang, one of the capital of Liaoning Province, and Dalian, one of the famous port cities located at the southern tip of Liaodong Peninsula, are interrelated and develop harmoniously, forming the backbone of Liaoning regional tourism system, and it is a typical "dual core" structural mode([2]).

Existing studies on urban agglomeration in Liaoning Province mainly focus on the economic growth of urban agglomeration with Shenyang as the center. A variety of methods have been used in the literature for map comparison and model verification to evaluate the simulation performance of urban growth model of Shenyang metropolitan circle in China([5]). Regarding the industrial structure of Liaoning urban agglomeration, the industrial structure and economic growth structure of the urban agglomeration are better than the contrast area when the cities outside the urban agglomeration are taken as the contrast area. Therefore, resource-based cities, such as Fushun and Fuxin, can make use of the advantages of industrial priority and urban system interaction to realize the strategy of urban economic transformation([6]). When studying the coupling degree of spatial energy consumption and industrial structure, the coupling degree of energy efficiency and industrial structure in Liaoning is low except that of Shenyang and Dalian([7]). The main research is based on the relationship between air pollution and the urban agglomeration in the central of Liaoning([3]). With the development of social economy, environmental problems are becoming more and more serious, especially urban carbon dioxide emissions. In order to quantify the driving force of carbon dioxide emissions in China's cities, it is necessary to consider the comparative analysis between the level of the state and the urban agglomeration([8]).

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Table 1. Population, GDP and Inter City Distance in Liaoning

City	Non farm population (10000)	GDP (100 million yuan)	Dalian	Shenyang	Anshan	Yingkou	Panjin
Dalian	7668.5	698.75					
Shenyang	6292.4	829.4	370				
Anshan	1751.1	344	298.9	82.8			
Yingkou	1346.7	243.8	216.8	175.3	95.8		
Panjin	1216.6	143.65	229.6	178.8	99.4	15.1	
Jinzhou	1192.4	296.4	361.8	224.4	178.1	147.2	132.8
Fushun	1048.8	210.7	420.5	53.4	133.4	225.9	229.9
Liaoyang	869.7	183.7	320.5	54.1	29.9	125.9	129.9
Chaoyang	831.4	295	454	299.2	262.6	239.5	225.1
Benxi	823.1	147.63	372.9	32	84.8	178.3	182.3
Dandong	816.7	239.5	294.8	238.3	232.4	254.5	261.1
Huludao	812.8	277	393.2	268.5	218.9	178.6	164.2
Tieling	616.6	299.8	439	72.2	152.4	244.4	246.3
Fuxin	446	186.2	399.5	183.3	176.1	185	170.6

City	Jinzhou	Fushun	Liaoyang	Chaoyang	Benxi	Dandong	Hulu dao	Tieling	Fuxin
Dalian									
Shenyang									
Anshan									
Yingkou									
Panjin									
Jinzhou									
Fushun	267.5								
Liaoyang	203.7	105.4							
Chaoyang	96.7	348.3	291.7						
Benxi	243.6	62.4	55.4	321.9					
Dandong	370.4	257.3	220.5	455.6	206.7				
Huludao	54.4	311.7	247.8	124.5	288	403.1			
Tieling	275.9	56.7	123.6	326.2	98.2	302.8	319.9		
Fuxin	122.2	218.6	181.9	132.4	213.5	400.1	174.6	199.8	

The research mentioned above lacks the analysis and definition of the current urban agglomeration of Liaoning Province. Gravity model is a common tool to divide the economic attraction between cities [9]. It can be used to basically divide the level of urban agglomeration according to the strength of the level of economic attraction([10]).Based on gravity model, the present situation of Liaoning urban agglomeration is analyzed by using ArcGIS and UCINET.

3 Data and model

3.1 Data

The paper selects 14 cities in Liaoning Province, and the shortest distance between cities calculated and the coordinates of urban longitude and latitude data come from the Baidu map. The GDP and population data of each city were collected from the National Statistical Yearbook. Administrative divisions refer to the Bureau of Surveying, Mapping and Geographic Information.

3.2 Gravity model

Gravity model is one of the successful examples in many fields. Now, gravity models can be applied to many fields, including the impact of settlement migration, traffic flow, trade, etc. Gravitational model in geoeconomics is the equation of the interaction between two places based on the law of Newton's universal gravitation: the two population centers in a region attract each other in proportion to the product of their size, and are inversely proportional to the square of the distance between them. d_{ij} is defined as the distance between objects I and J . m_i and m_j are the masses of objects I and J , respectively. K is constant. Then Newton theory draws the gravitational attraction T_{ij} between I and J .

$$T_{ij} = km_i m_j d^{-2} \quad (1)$$

Therefore, Newton's theory can be used to explain the patterns of certain human activities between physically separated entities in space. In the mid 1850s, this theory was first applied to the overall structure of movement and communication generated by behavioral decision making processes for linkage, demand / supply decisions or site selection. In brief, it was used to analyze spatial interaction([11]). In these pioneering applications, gravity is replaced by the strength of the interaction between two regions, expressed in terms of the distance or number of moves between the two regions, and the mass needs to be defined according to the type of activity being modeled. Until Stewart's work (1941), quality is defined as the origin and destination of the floating population([12]). Based on the above, we can establish an inter city gravity model:

$$T_{ij} = K_{ij} (\sqrt{P_i G_i \bullet P_j G_j} / R_{ij}^\beta) \quad (2)$$

T_{ij} is the attraction of I city and J City, P_i and P_j are the staff members of the non-agricultural sector of i city and j City. K is the coefficient. R_{ij} shows the distance between cities and β shows the friction paramete. It can be applied to the urban agglomerations, then we can get urban gravitational matrix T . T indicate the economic attractiveness of cities in the urban agglomeration, that is, the flow of social or economic factors.

Therefore, we can obtain the representation of the connection level between city i and other cities:

$$L_i = T_i / \sum T_{ij} \quad (3)$$

L_i indicates the intensity of economic ties between urban i and urban j . It is an indicator of the degree of economic dependence of cities in a city group or the trend of developing into a strong city.

4 Empirical analysis

4.1 Gravitational matrix

Population, GDP and distance between cities in Liaoning province are shown in table 1.

Define k_i :

$$k_i = G_i / (G_i + G_j) \quad (4)$$

k_i here only expresses the gravitational coefficient of a large GDP city to a small GDP city. From table 1 and formula 2, we can get the gravitational matrix between different cities in Liaoning province, as shown in Table 2.

From the gravitational matrix of Table 2, we can see that there are significant differences in the economic links between cities. The visualization of ArcMap data is shown in figure 1.

According to the formula (3), we can get the link rank relationship between other cities and Dalian Shenyang, which is supposed to be the core city, as shown in Table 3 and Table 4.

4.1 Urban agglomeration Division

Redefine k_i as new bidirectional matrix that is calculated by combining Table 1 with the gravitational coefficient of all cities, as shown in Table 5.

Table 2. Economic Gravitational Matrix of Prefecture Level Cities in Liaoning Province

	Dalian	Shenyang	Anshan	Yingkou	Panjin	Jinzhou	Fushun	Liaoyang	Chaoyang	Benxi	Dandong	Huludao	Tieling	Fuxin
Dalian														
Shenyang	78.5													
Anshan	48.9	167.5												
Yingkou	52.0	61.5	26.2											
Panjin	36.4	44.8	19.3	83.3										
Jinzhou	32.9	50.9	15.4	12.3	9.5									
Fushun	22.8	172.4	17.1	6.7	4.6	5.6								
Liaoyang	25.9	148.3	69.3	11.1	7.5	6.7	9.7							
Chaoyang	22.8	33.4	9.9	7.3	5.5	17.9	3.7	3.5						
Benxi	19.5	220.1	21.7	7.0	4.8	5.0	14.7	12.9	2.7					
Dandong	31.4	37.5	10.1	6.2	4.2	4.2	4.5	4.1	2.4	3.7				
Huludao	25.3	35.8	11.5	9.5	7.2	30.8	4.0	4.0	9.5	2.9	2.6			
Tieling	21.0	123.9	16.2	6.9	4.8	6.1	22.4	8.1	3.7	8.7	3.6	3.6		
Fuxin	15.8	33.5	10.1	6.7	5.2	10.2	4.3	4.2	7.0	3.1	2.1	5.1	3.6

Fig. 1. Economic Links Between Liaoning Cities.

Table 3. The Relationship Strength Between Other Cities And Dalian

Dalian	Economic attraction	$\sum T_{ij}$	$T_i / \sum T_{ij}$	Grade
Shenyang	78.51	433.19	0.181	1
Yingkou	52.04	433.19	0.120	1
Anshan	48.93	433.19	0.113	1
Panjin	36.38	433.19	0.084	2
Jinzhou	32.92	433.19	0.076	2
Dandong	31.38	433.19	0.072	2
Liaoyang	25.93	433.19	0.060	2
Huludao	25.26	433.19	0.058	2
Chaoyang	22.78	433.19	0.053	2
Fushun	22.76	433.19	0.053	2
Tieling	20.98	433.19	0.048	3
Benxi	19.54	433.19	0.045	3
Fuxin	15.78	433.19	0.036	3

Table 4. The Relationship Strength Between Other Cities And Shenyang

Shenyang City	Economic attraction	$\sum T_{ij}$	$T_i / \sum T_{ij}$	Grade
Benxi	220.07	1129.52	0.195	1
Fushun	172.38	1129.52	0.153	1
Anshan	167.52	1129.52	0.148	1
Liaoyang	148.29	1129.52	0.131	1
Tieling	123.90	1129.52	0.110	1
Yingkou	61.51	1129.52	0.054	2
Jinzhou	50.88	1129.52	0.045	3
Panjin	44.76	1129.52	0.040	3
Dandong	37.53	1129.52	0.033	3
Huludao	35.75	1129.52	0.032	3
Fuxin	33.54	1129.52	0.030	3
Chaoyang	33.40	1129.52	0.030	3

Table 5. Bidirectional Gravity Matrix of Prefecture-level Cities in Liaoning Province

	Dalian	Shenyang	Anshan	Yingkou	Panjin	Jinzhou	Fushun	Liaoyang	Chaoyang	Benxi	Dandong	Huludao	Tieling	Fuxin
Dalian		78.5	48.9	52.0	36.4	32.9	22.8	25.9	22.8	19.5	31.4	25.3	21.0	15.8
Shenyang	64.4		167.5	61.5	44.8	50.9	172.4	148.3	33.4	220.1	37.5	35.8	123.9	33.5
Anshan	11.2	46.6		26.2	19.3	15.4	17.1	69.3	9.9	21.7	10.1	11.5	16.2	10.1
Yingkou	9.1	13.2	20.2		83.3	12.3	6.7	11.1	7.3	7.0	6.2	9.5	6.9	6.7
Panjin	5.8	8.7	13.4	75.3		9.5	4.6	7.5	5.5	4.8	4.2	7.2	4.8	5.2
Jinzhou	5.1	9.6	10.5	10.9	9.3		5.6	6.7	17.9	5.0	4.2	30.8	6.1	10.2
Fushun	3.1	28.7	10.2	5.2	4.0	4.9		9.7	3.7	14.7	4.5	4.0	22.4	4.3
Liaoyang	2.9	20.5	34.4	7.1	5.4	4.9	8.1		3.5	12.9	4.1	4.0	8.1	4.2
Chaoyang	2.5	4.4	4.7	4.5	3.7	12.5	3.0	3.3		2.7	2.4	9.5	3.7	7.0
Benxi	2.1	28.8	10.2	4.2	3.2	3.5	11.5	12.2	2.7		3.7	2.9	8.7	3.1

Dandong	3.3	4.9	4.7	3.8	2.8	2.9	3.5	3.9	2.4	3.7		2.6	3.6	2.1
Huludao	2.7	4.6	5.3	5.7	4.8	21.0	3.1	3.7	9.3	2.9	2.6		3.6	5.1
Tieling	1.7	12.1	5.7	3.2	2.5	3.2	13.2	5.8	2.8	6.5	2.7	2.8		3.6
Fuxin	0.9	2.4	2.6	2.2	1.9	3.8	1.8	2.1	3.8	1.7	1.1	2.8	2.6	

I import table3 data into UCINET to realize data visualization and get figure 2.

The degree of line thickness indicates the strength of economic attraction between cities. The size of the urban punctuation indicates the strength of the other cities and their economic gravity. The red point indicates that the city group with the strongest intercity economic ties, the blue city group is the next, while the gray represents the marginal city group.

From the diagram, we can see the following points: firstly, the strongest economic gravitational relationship is around the core city of Shenyang. The core city group consists of Shenyang, Liaoyang, Benxi, Anshan, Fushun and Tieling. Unlike the mentioned theory about five cities in the central city group of Liaoning, the study also finds that Tieling has strong economic attraction with Shenyang, which should be attributed to the central cities of Liaoning. In these six cities, Anshan and Liaoyang have strong economic attraction lines except Shenyang and other cities.

Secondly, Dalian, Yingkou, Panjin, Huludao and Jinzhou constitute an urban agglomeration with the second strongest gravity links. It can be seen from the graph that Huludao and Jinzhou have stronger economic attraction than Dandong and other three cities.

Finally, Dandong, Fuxin and Chaoyang are marginal cities. Apart from forming a certain economic gravitational strength with Shenyang, they have weak gravitational relations with other cities.

5 Conclusion

This paper simulates the economic gravitation between cities in 14 prefecture level cities in Liaoning province by gravity model, and realizes data visualization through ArcMap and Ucinet software. Compared with the Liaoning central city group and the southern Liaoning city group mentioned above, this paper gives different views. It is concluded that the central city group of Liaoning is composed of Shenyang, Liaoyang, Benxi, Anshan, Fushun and Tieling, and the southern city group of Liaoning is composed of Dalian, Yingkou, Panjin, Huludao and Jinzhou.

There are still many deficiencies in this paper. The conclusion of the model still lacks other ways of testing. We hope to include other refined data in subsequent research and further verify the validity of the establishment of urban agglomeration.

Fig. 2. The Strength of Economic Attraction Between Cities.

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