Hindawi
Mathematical Problems in Engineering
Volume 2023, Article ID 1282914, 10 pages
https://doi.org/10.1155/2023/1282914

Research Article

Northeast China Urban Network Structure and Reorganization Based on the Coordinated Development Capability of Cities

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Received 20 September 2022; Revised 6 December 2022; Accepted 21 December 2022; Published 9 January 2023

Academic Editor: Madalina Dumitriu

Urban synergy can be assessed based on the development of a given city and the organization and development channels between cities. Using the entropy method, correction gravity model, and social network analysis, our study conducted a comprehensive quantitative analysis of the characteristics of urban network space in three northeast provinces in China. The region exhibited a "core city-peripheral city-marginal city" concentric pattern, with the most developed cities at the core. Nevertheless, our findings indicate that a collaborative development pattern is gradually forming. The three northeastern provinces and urban collaboration networks extended further to the north. Liaoning Province, most of Jilin Province, and most of Heilongjiang Province have gradually established a similar development relationship with other cities. The overall level of urban intermediary centers in the northeastern provinces is declining, and the direct contact between cities is becoming more apparent. These findings, in addition to agglomeration calculations, highlight the need for reorganizing the current collaborative urbanization structure in northeast China.

1. Introduction

Promoting the division of labor, cooperation, and coordinated development among cities is an effective path for regional development. The coordinated development of the three northeastern provinces of China (Heilongjiang, Jilin, and Liaoning) conforms to the current macrodevelopment trends and the development needs of this region. Coordinated development refers to the coordination of two or more administrative regions (e.g., provinces and prefecture-level cities) to achieve the same development goal based on the concept of win-win cooperation, the principle of complementary advantages, the requirements of industrial division of labor, and the carrying capacity of resources and the environment. Additionally, this new pattern of regional development integrates transportation infrastructure, industrial development and layout, factor markets, urban and rural areas, basic public services and livelihood, and environmental protection [1].

Based on the current national development trends, both urban agglomerations and the economic belt are committed to coordinated regional development. However, very few studies have been conducted in the field of urban collaboration, most of which have primarily focused on urban networks through a combination of theory and demonstration [2, 3], as well as qualitative and quantitative approaches [4]. Early theoretical studies on collaborative development in China include those conducted by Lu Lu [5] and Fang [6], among others, who studied the theoretical basis and principles of the collaborative development of the Beijing-Tianjin-Hebei urban agglomeration. From the perspective of interindustry collaboration, Peng [7] and Lin and Liu [8] studied the synergistic development capacity and driving factors of regional economies. Wu and Yu [9] and Jiayu et al. [10] conducted research on logistics and e-commerce, as well as tourism and urbanization. Gang et al. [11, 12] measured the synergistic capacity of cities in the Yangtze River Economic Belt and proposed a spatial division of cities in this region based on their results. Furthermore, Wang et al. [13] analyzed

the intercity economy and transportation within the Yangtze River Economic Belt from an urban network perspective. Yixing and Hu [14], Meng et al. [15], Ke et al. [16], and others constructed a network from a transportation perspective (i.e., including railways, air routes, and passenger flights) and discussed the urban system and spatial organization mode. Urban networks are constructed based on spatiotemporal flows, including population flow [17–19], passenger flow [20], and information flow (Baidu index) [21].

Current research on synergetic development, both in China and other countries, has remained highly focused on certain fields, such as interindustry, interenterprise, or industry-university-research relationships. In contrast, very few studies have explored synergetic development at the city level, and these studies have mainly focused on the overall mechanisms of urban synergetic development. The present study was heavily inspired by the findings of Zeng Gang's team. Our study evaluated 34 cities in the three northeastern provinces of China. Specifically, our study conducted a quantitative analysis of the level of urban collaborative development and further construction of urban networks, the spatiotemporal evolution characteristics of urban collaborative development, and the characteristics of urban networks in the three provinces of northeast China according to condensed subgroups. Finally, our study proposed potential strategies for the integration and reorganization of the urban spatial structure in the three northeastern provinces of China.

2. Overview of the Study Area, Data Sources, and Research Methods

2.1. Overview of the Study Area. The three northeastern provinces studied herein include Heilongjiang, Jilin, and Liaoning (Figure 1). The spatial organization units of these provinces included the Harbin Da-Qi industrial corridor, the Jilin central city group, the Liaoning central south city group, the Shenyang economic zone, the Changjitu development and opening-up pilot zone, Heilongjiang Province's "14th Five-year Plan" proposed to build the Harbin modern metropolis circle (one-hour and two-hour economic circles), and the Heilongjiang eastern group.

Our study considers the 14th Five-year Plan of Jilin Province, which proposes to build the Changchun modern metropolitan area, as well as the 14th Five-year Plan of Liaoning Province, which proposes to build the Shenyang metropolitan area. Our study also includes the Liaoning coastal economic belt, the western Liaoning, and the Beijing-Tianjin-Hebei pilot area coordinated development strategy, as well as the Eastern Liaoning green economic zone. Moreover, the national "14th Five-year Plan" established a strategy to develop the central and southern Liaoning city group and Harbin city group. In summary, the spatial organization units of the three northeastern provinces change frequently and are constantly in development. By measuring the capacity of urban collaborative development in the three northeastern provinces, the present study conducted a spatial reconstruction of the obtained data to aid in the future urban and infrastructure planning of this region.

2.2. Data Sources. The northeast revitalization strategy was officially implemented for the first time in 2003, and the state continued to introduce a new round of northeast revitalization policies in 2013. Given the data availability and timeline, our study evaluated urbanization trends five years before and after 2013 (2008–2018) to better grasp the evolution of urban spatial development. The data sources included the China Urban Statistical Yearbook, the Heilongjiang Statistical Yearbook, the Jilin Statistical Yearbook, the Liaoning Statistical Yearbook, and other data released by relevant institutions. Data from the Greater Khingan Mountains and Yanbian Korean Autonomous Prefecture are not included in this study.

2.3. Materials and Methods

2.3.1. Modified Gravity Model. From the perspective of urban linkages, the "quality" of a city is determined by its level of comprehensive development. In this study, the time of intercity railway passenger transport is taken as the time-cost distance. The empirical constant "K" was corrected by substituting the weight of the city "quality" with the sum of the "quality" of the two linked cities. The modified gravity model can be expressed as follows:

$$F_{ij} = \frac{E_i}{E_i + E_j} \times \frac{\sqrt[3]{E_i} \times \sqrt[3]{E_j}}{T_{ij}^2}, \tag{1}$$

where F_{ij} is the city-to-city synergy strength, E_i and E_j are the synergy levels of cities i and j, and T_{ij} is the time-cost relationship between cities i and j.

2.3.2. Social Network Analysis Method

(1) Network Density. Network density is an analysis of the overall status of the correlation strength of coordinated development among cities in the three northeastern provinces. The stronger the urban synergy, the closer the connection between cities within the network, and the greater the network density. Network density can be calculated as follows [16]:

$$D = \sum_{i=1}^{k} \sum_{j=1}^{k} \frac{d(i,j)}{k(k-1)}, \tag{2}$$

where D is the network density, k is the number of city nodes, and $d_{(i,j)}$ is the synergy link strength between cities i and j.

(2) Network Centrality. (a) Degree centrality: degree centrality is used to measure the synergy and connection capacity between cities within the network. Cities with a synergistic connection with a larger number of other cities possess a higher degree of centrality. It shows that the city is in an important position in the whole network and has strong competitiveness of collaborative development. Degree centrality can be calculated as follows [16]:

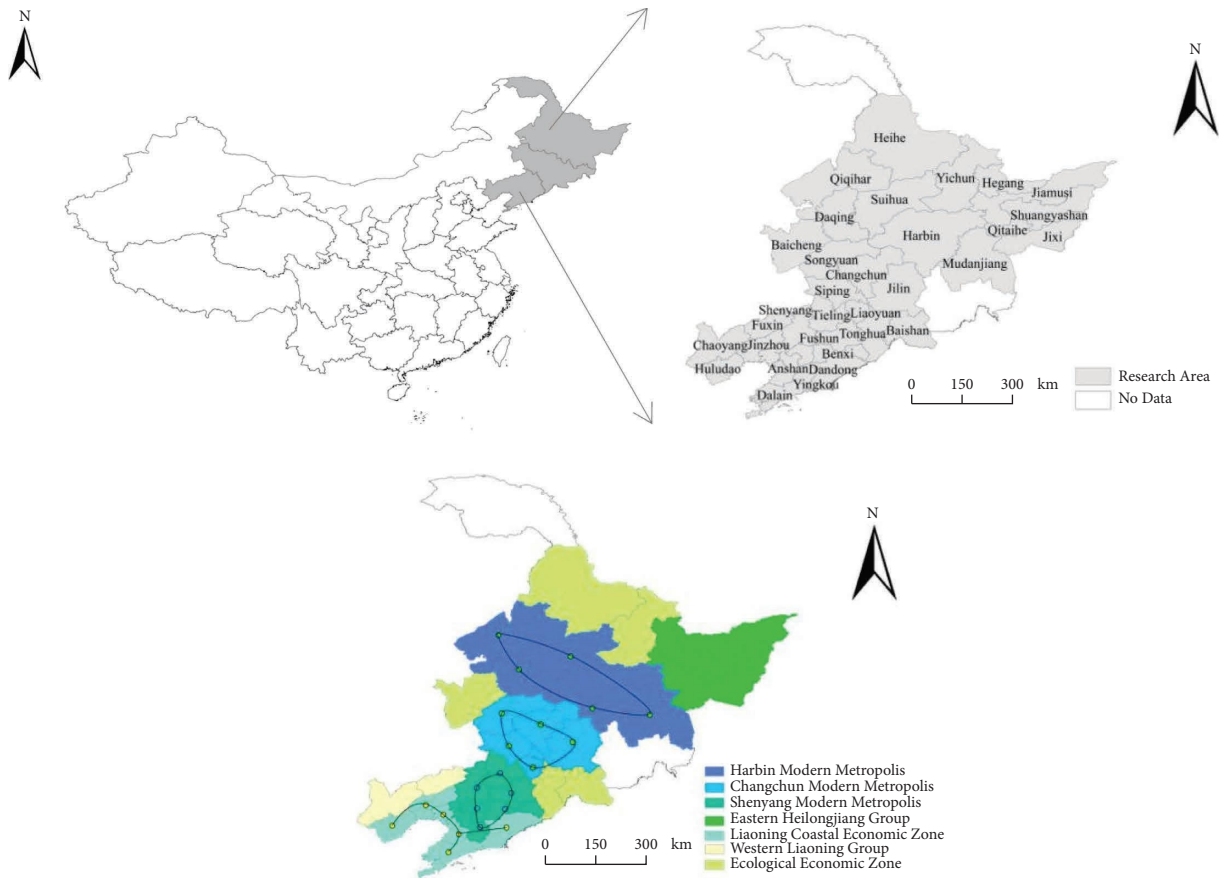

Figure 1: Study area and spatial geographic units.

$$CD_i = \sum_{j=1}^{n} X_{ij}, \tag{3}$$

where CD_i is the degree centrality of city i and X_{ij} is the strength of the synergistic linkage between cities i and j.

(b) Between centrality: between centrality refers to the degree to which the synergy between two non-neighboring cities depends on other cities. It indicates how capable a city is to become a "bridge" for synergy between other cities, reflecting its ability to connect and influence other cities. The higher the intermediary centrality of the city, the stronger the contact control ability, and the closer it is to the core position of the network. This parameter can be expressed as follows [16]:

$$CB_i = \sum_{j}^{n} \sum_{k}^{n} \frac{g_{jk}(i)}{g_{jk}}, \tag{4}$$

where CB_i is the between centrality of city i, g_{jk} is the number of connections between city i and j, and $g_{ik}(i)/g_{jk}$ represents the probability that city i is located within the connection between city j and city k.

(3) Cohesive Subgroups. Cohesive subgroups are a collection of cities with high connection strength and cohesion of the urban synergy network. In this study, these groups were obtained using the Network ⟶ Roles and Positions ⟶ Structural ⟶ Convergent Correlations (CONCOR) function in UCINET based on the strength of urban synergy to explore urban clusters in the three northeastern provinces. In turn, these analyses identified strong and weak relationships between cities and allowed for the integration and reorganization of the spatial units of the three northeastern provinces.

3. Measurement of Coordinated Development Capacity of Cities in the Three Northeastern Provinces

3.1. Establishment of an Evaluation Index System to Assess the City's Collaborative Development Capacity. According to the definition of collaborative urban development and based on current research results, an evaluation index system was created to cover four aspects of collaborative urban development, including economic development, social development, ecological environment, and infrastructure. These four broad classifications encompassed 20 indicators, including GDP, Internet users, and unemployment rates (Table 1). Among them, economic development capacity is the core indicator of a city's external connection and further development. The construction of facilities (i.e., infrastructure) is necessary to enable a city's communication, promote intercity cooperation, and divide labor within the region. Moreover, social coordination is an important link to ensure the harmonious and stable development of cities.

Table 1: Proposed index system to assess the collaborative development capacity of cities.

Target layer	Element layer	Index layer
City's collaborative development capacity	Economic synergy	Economic aggregate (100 million yuan), location entropy of primary industry, location entropy of the secondary industry, tertiary industry location entropy, economic efficiency (100 million yuan/100 million people), total retail sales of consumer goods (100 million yuan), and actual use of foreign capital (ten thousand dollars)
	Infrastructure coordination	Highway passenger traffic (10,000 people), road freight volume (10,000 tons), number of Internet users (ten thousand), number of postal and telecommunications services (ten thousand yuan), number of mobile phones (ten thousand households), and books in public libraries per 100 people (books, pieces)
	Social collaboration	Unemployment rate(%), number of hospital beds per 10,000 people (pieces), investment in science, technology, and education (ten thousand yuan)
	Environmental synergy	Sewage discharge per unit of industrial output value (10,000 tons/100 million yuan), comprehensive utilization rate of industrial solid waste (%), green coverage rate in built-up areas (%), and average output value of secondary and tertiary industries (100 million yuan/square kilometer)

Environmental sustainability is another core component of northeast China's development.

3.2. Collaborative Development Capacity Scores and Ranking of Cities. According to the urban collaborative development score from 2008 to 2018(Table 2), the collaborative development capacity of some cities increased whereas that of others decreased. Among them, the synergistic development capacity of 23 cities decreased, including core cities such as Dalian, Shenyang, and Changchun. In contrast, the coordinated development capacity of 11 cities increased, with Harbin having the most representation. It is also worth noting that 9 of the 11 cities with enhanced synergistic capacity were located in Heilongjiang Province.

These variations in urban coordination capacity were attributed to changes in the weights of economic synergy, facility synergy, social synergy, and environmental synergy from 0.462, 0.332, 0.165, and 0.041 in 2008 to 0.482, 0.297, 0.149, and 0.073 in 2018, with substantial increases in the economic and environmental weights. However, in an effort to achieve rapid economic growth, most cities find it challenging to achieve an optimal balance between economic and environmental factors, and therefore several indicators of environmental coordination have decreased to varying degrees, which ultimately weakens the overall coordination ability of cities. The coordination capacity of 9 cities in Heilongjiang Province increased, which was mainly due to their relatively balanced development in terms of economic and environmental parameters.

Upon ranking the coordinated urban development scores, the top four cities (Harbin, Changchun, Shenyang, and Dalian) were the same in 2008 and 2018. Therefore, these four core cities have always been at the center of the coordinated development of the three northeastern provinces.

3.3. Spatial Evolution Characteristics of Urban Collaborative Development Capacity. As illustrated in Figure 2, the overall distribution of the coordinated development capacity of cities in the three northeastern provinces remained largely unchanged from 2008 to 2018, with the highest capacities occurring at the center of the region, whereas the surrounding cities exhibited lower values. In terms of hierarchy, the region exhibited a three-level distribution in

Table 2: Ranking of cities in the three northeastern China provinces based on their coordinated development capacity score.

Rank	2008		2018	
	Urban	Score	Urban	Score
1	Shenyang	0.852	Dalian	0.687
2	Dalian	0.818	Shenyang	0.641
3	Changchun	0.593	Harbin	0.632
4	Harbin	0.553	Changchun	0.464
5	Daqing	0.311	Siping	0.274
6	Anshan	0.296	Suihua	0.266
7	Jilin	0.286	Jilin	0.234
8	Songyuan	0.215	Qiqihar	0.224
9	Qiqihar	0.211	Anshan	0.216
10	Jinzhou	0.209	Daqing	0.211
11	Yingkou	0.200	Jinzhou	0.210
12	Dandong	0.200	Mudanjiang	0.201
13	Siping	0.197	Yingkou	0.191
14	Liaoyang	0.188	Songyuan	0.184
15	Fushun	0.184	Jiamusi	0.184
16	Panjin	0.181	Dandong	0.176
17	Benxi	0.181	Panjin	0.167
18	Mudanjiang	0.176	Chaoyang	0.159
19	Tieling	0.176	Huludao	0.155
20	Suihua	0.174	Heihe	0.154
21	Tonghua	0.172	Jixi	0.152
22	Jiamusi	0.165	Tonghua	0.152
23	Huludao	0.161	Tieling	0.150
24	Chaoyang	0.161	Liaoyang	0.140
25	Baicheng	0.155	Baicheng	0.137
26	Jixi	0.143	Fushun	0.133
27	Liaoyuan	0.140	Benxi	0.132
28	Shuangyashan	0.131	Fuxin	0.122
29	Baishan	0.126	Yichun	0.121
30	Heihe	0.125	Hegang	0.120
31	Fuxin	0.125	Baishan	0.114
32	Yichun	0.102	Shuangyashan	0.113
33	Hegang	0.101	Liaoyuan	0.104
34	Qitaihe	0.086	Qitaihe	0.082

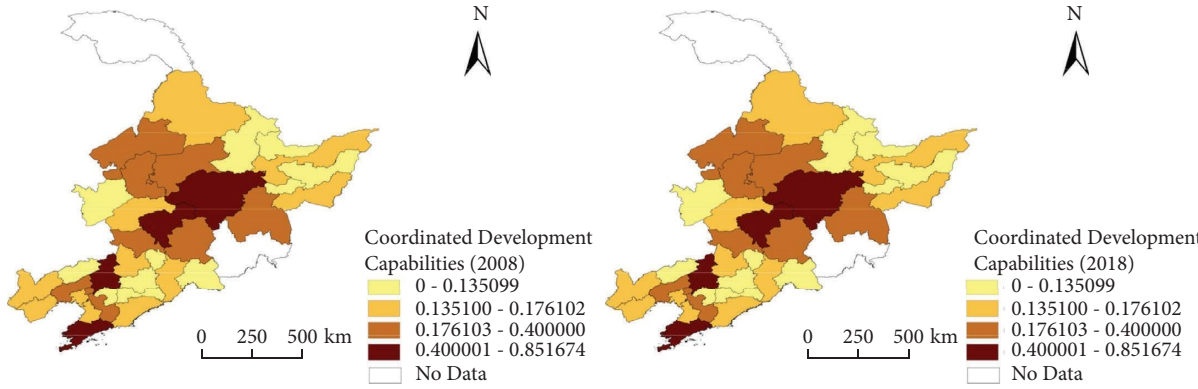

Figure 2: Coordinated development capabilities.

collaborative development capacity that exhibited the following decreasing order: core city > peripheral city > marginal city. Harbin, Changchun, Shenyang, and Dalian constituted the core, whereas the collaborative development capacity of the surrounding cities was weak and that of remote and marginal areas was the weakest. By 2018, the synergistic development capacity of the cities in the three northeastern provinces was further polarized with the four major cities as the core, whereas the areas with strong synergistic capacity were further concentrated. This phenomenon was most obvious in Liaoning Province; however, Benxi, Fushun, Liaoyang, and even Dandong also exhibited a significant decline. The synergistic development capacity of individual remote and marginal areas was also further weakened. The northern region was mainly represented by Yichun, Hegang, and Shuangyashan, whereas the central and southern regions were represented by Fuxin, Baishan, Benxi, and Fushun. These cities are resource-exhausted and located in the marginal areas of the three northeastern provinces, and are thus facing great difficulties in industrial transformation and maintain a low level of synergistic development capacity.

4. Characteristics of the Collaborative Network Structure of Cities in the Three North Eastern Provinces

4.1. Analysis of Overall Network Density. Using the network density formula to quantitatively measure the network density of urban coordination in the three northeastern provinces, our study found that the network density increased significantly from 0.128 in 2008 to 0.489 in 2018. These findings indicate that although the urban collaborative capacity of several cities has declined to varying degrees, a pattern of urban collaborative development is gradually forming in the three provinces of northeast China (Figure 3). In other words, intercity connections have not weakened due to the decline of urban collaborative capacity. In contrast, increasingly more cities have incorporated themselves into this pattern of coordinated urban development, which is closely related to the improvement of traffic conditions in northeast China over the past few years. Interestingly, there were several outliers in the collaborative network of cities in the three northeastern provinces in 2008; however, in 2018, these outliers were no longer identified, and the collaborative development links between core nodes, core nodes and edge nodes, and edge nodes were generally established.

4.2. Analysis of Centrality Characteristics

4.2.1. Degree Centrality Analysis. In 2008 and 2018, the value ranges of urban point centrality were 0.00012–9.99495 and 2.00271–24.99080, respectively. The value range increased from 9.99483 to 22.98809, indicating that the gap between the most connected and weakest cities in the network increased. Based on the synergistic development of cities, our findings indicated that the strongest cities generally became stronger whereas the weakest became weaker. Spatial visualization was conducted using the inverse distance weight interpolation method in ArcGIS, and the spatial evolution process of point degree centrality of the urban cooperation network in the three northeastern provinces was obtained (Figure 4).

In 2008, the core of the urban collaborative network was mainly concentrated in Liaoning Province, with Shenyang as the center, and spread to the periphery. In contrast, Changchun and Harbin, which lacked a strong point centrality, were located at the edge of the urban collaborative pattern. Although Dalian had a strong urban collaborative development capacity, its location decreased its centrality value, which made it difficult to assess its spatial synergistic role.

By 2018, the urban collaborative network had been further extended to the north, and most cities in Liaoning Province, Jilin Province, and Heilongjiang Province had gradually established collaborative development relationships with other cities, and the transprovincial and transregional cooperation model had been gradually established. Heihe, Yichun, Hegang, Jimusi, Jixi, Shuangyashan, Baishan, and Baicheng have historically constituted a "low-value area." This area is located at the edge of the study region and is relatively closed, with slow infrastructure and social development, and is largely composed of resource-exhausted or ecologically sensitive cities. It is worth noting that a "high-value area" with Changchun and Harbin at its core gradually took shape, and the synergistic effect of the cities of Harbin,

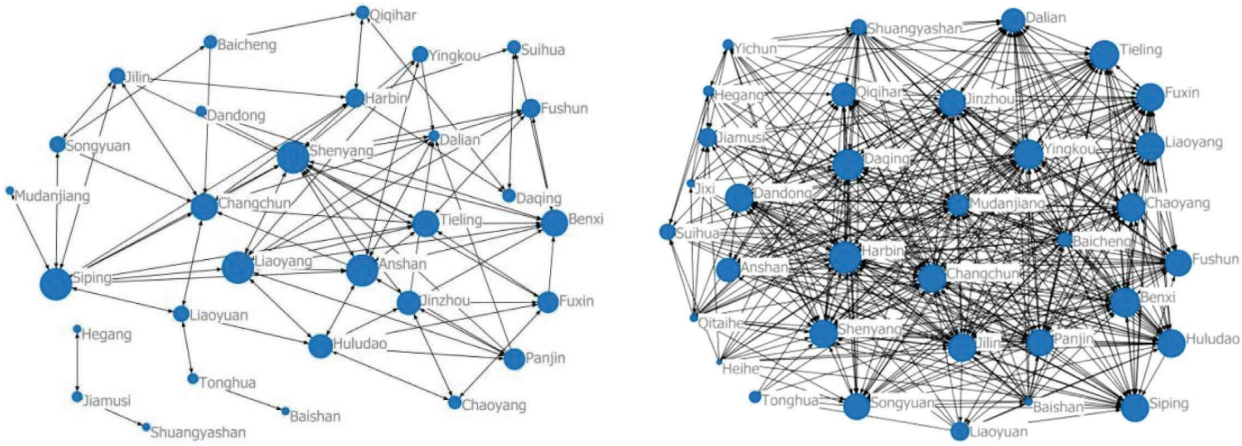

Figure 3: City collaboration network diagram. (a) 2008. (b) 2018.

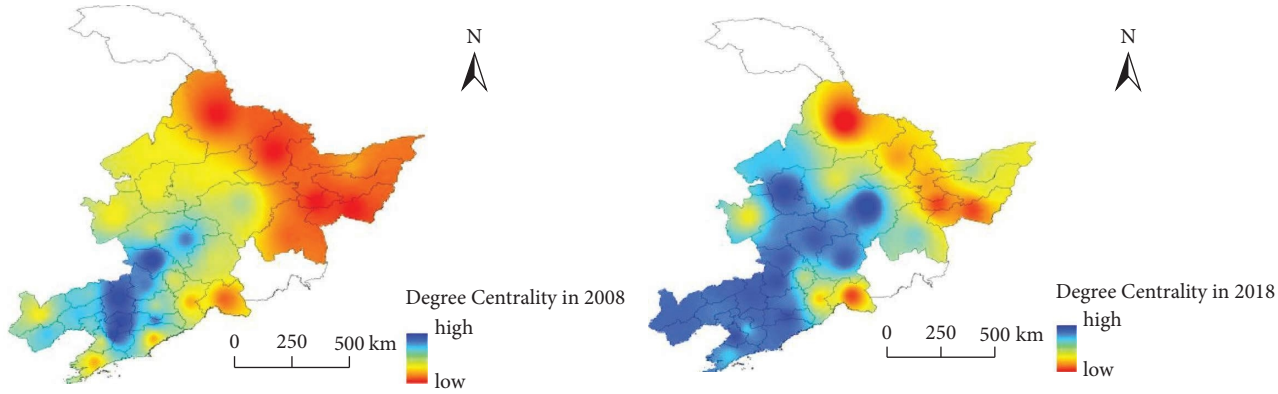

Figure 4: Spatial evolution of urban centrality in the study area.

Suihua, Daqing, and Mudanjiang was significantly enhanced. Our findings also demonstrated that the "Ha-Chang Urban Agglomeration" proposal provides a good opportunity for the coordinated development of the whole region. The "high-value area," with Shenyang and Anshan at its core, has a radiating and driving effect, which significantly improves the external connection intensity of all cities in Liaoning Province.

4.2.2. Analysis of Between Centrality. As illustrated in Figure 5, Changchun, Shenyang, Siping, and Harbin exhibited a high intermediary centrality in 2008, whereas the rest of the cities had lower values. Most cities were mainly connected through these intermediary cities. In 2018, the degree of intermediary centrality of cities located on the main axis of Harbin and Dalian all declined to varying degrees. However, Harbin's intermediary centrality significantly increased, indicating that this city plays an increasingly prominent role as a "bridge" to the northern regions of the three northeastern provinces, and the intercity connection formed a coordinated development pattern that strongly relies on Harbin.

In summary, the overall level of urban intermediary centrality in the three northeastern provinces exhibited a downward trend from 2008 to 2018, indicating that communication with a third city was no longer necessary to facilitate the coordinated development of cities. Instead, the two cities established direct links, and the development of the three northeastern provinces tended to be more coordinated.

5. Spatial Integration and Reorganization of the Three Provinces in Northeast China from the Perspective of Urban Coordinated Development

The level of urban collaborative development can comprehensively reflect the growth of a given region, and the evolution of urban collaborative networks can effectively reflect the characteristics of urban spatial organization within a region, as well as allowing for the identification of spatiotemporal trends in urban organization. Based on the analysis of urban network density, centrality, and condensed subgroups, this study further discusses the spatial integration and

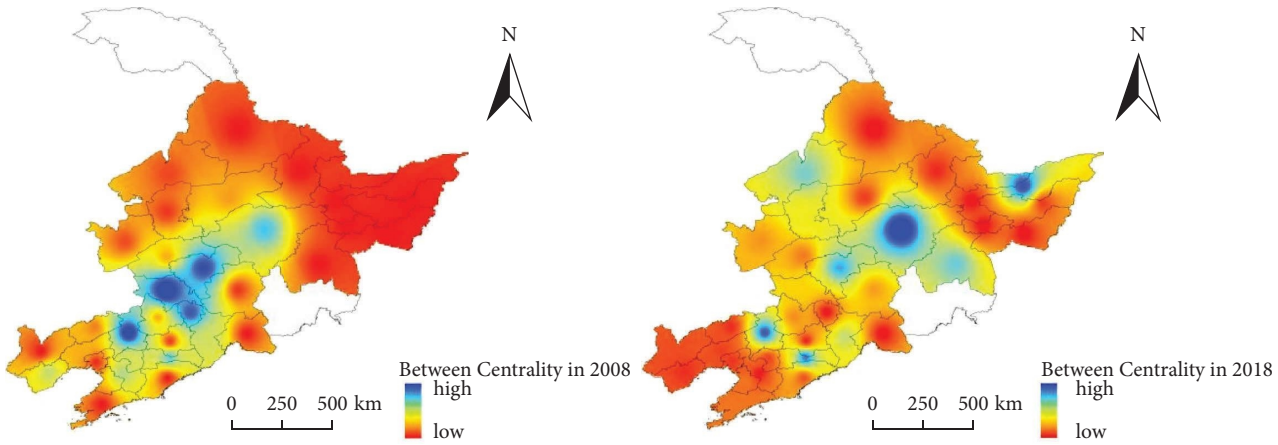

Figure 5: Spatial evolution of between centrality.

reorganization of the three northeastern provinces from the perspective of coordinated urban development.

5.1. Analysis of the Evolution of Condensed Subgroups. Based on the strength of intercity connections, condensed subgroups can reflect the agglomeration of small groups through regional connections and can distinguish the state of core groups and intergroup connections of cities according to their density and composition.

The ArcGIS software was used to plot the spatial distribution of the condensed subgroups (Figure 6), and the cities in the three northeastern provinces were divided into four subgroups. Subgroup 1 included Harbin, Changchun, Shenyang, Qiqihar, Songyuan, and Mudanjiang. Subgroup 2 included Daqing, Jilin, Siping, and all cities in Liaoning Province except for Shenyang. Subgroup 3 included Heihe, Shuangyashan, Jixi, Baicheng, Tonghua, and Baishan. Subgroup 4 is concentrated and contiguous in Heilongjiang Province, including Suihua, Yichun, Hegang, Jiamusi, and Qitaihe. From the perspective of spatial distribution, Subgroup 1 and Subgroup 2 were largely distributed in the central areas of the three northeastern provinces and all of Liaoning Province. However, there is a certain degree of separation between these subgroups. Subgroup 4 is the most complete and is distributed across the northern part of Heilongjiang Province, whereas Subgroup 3 is the most fragmented. These subgroups were distributed across northern and eastern Heilongjiang Province and western and eastern Jilin Province. The UCINET software was used to obtain the condensed subgroup density matrix (Table 3). Subgroup 1 had the highest density, followed by Subgroup 2. Although the two belong to different subgroups, their densities, and cooperative attributes/capacity were very similar.

5.2. Analysis of Regional Spatial Organization Reconstruction of the Three Northeastern Provinces. Based on our findings, this study proposes some strategies for the integration and reorganization of the spatial organization pattern of the three northeastern provinces in combination with the national 14th Five-Year Plan, the provincial 14th Five-Year Plan, the territorial spatial plan, and other relevant policy documents. These strategies are outlined below:

(1) Subgroup 1 should be used as the core to reconstruct the Harbin-Yangtze urban agglomeration. This city cluster includes Harbin, Changchun, Qiqihar, Daqing, Suihua, Mudanjiang, Jilin, Songyuan, Siping, Liaoyuan, and the Yanbian Korean Autonomous Prefecture (no data were available for the latter). Based on our findings, Suihua City has a low level of coordination capacity and point centrality and belongs to Subgroup 4. Therefore, this study suggests that Suihua, Yichun, Hegang, Jiamusi, and Qitaihe can form a group of cities in northeast Heilongjiang Province. Daqing city, Jilin city, and Liaoyuan city, which belong to the second sub-group, are still kept within the Harchang-Harbin urban agglomeration, considering the adjustment of location conditions and administrative divisions. However, Siping city in Jilin Province is located on the main traffic axis between Harbin and Dalian and has had a closer economic and social connection with Liaoning Province for a long time. Therefore, the Shenyang Metropolitan Circle should avoid administrative barriers and incorporate Siping City into its economic development plans.

(2) The entire spatial development pattern of Liaoning Province was constructed with Subgroup 2 as the core. The spatial organization pattern of Liaoning Province is mainly composed of the Shenyang Economic Zone (metropolitan area) and the Liaoning Coastal Eonomic Zone. Our synergy capacity measurements and subgroup cohesiveness analyses indicated that all cities in Liaoning Province except for Shenyang belong to the first subgroup, whereas all other cities belong to the second subgroup. However, considering the small difference between the first and second subgroups, Liaoning province can still be regarded as a complete spatial organization unit. The initiative of fostering urban agglomeration in central and southern Liaoning

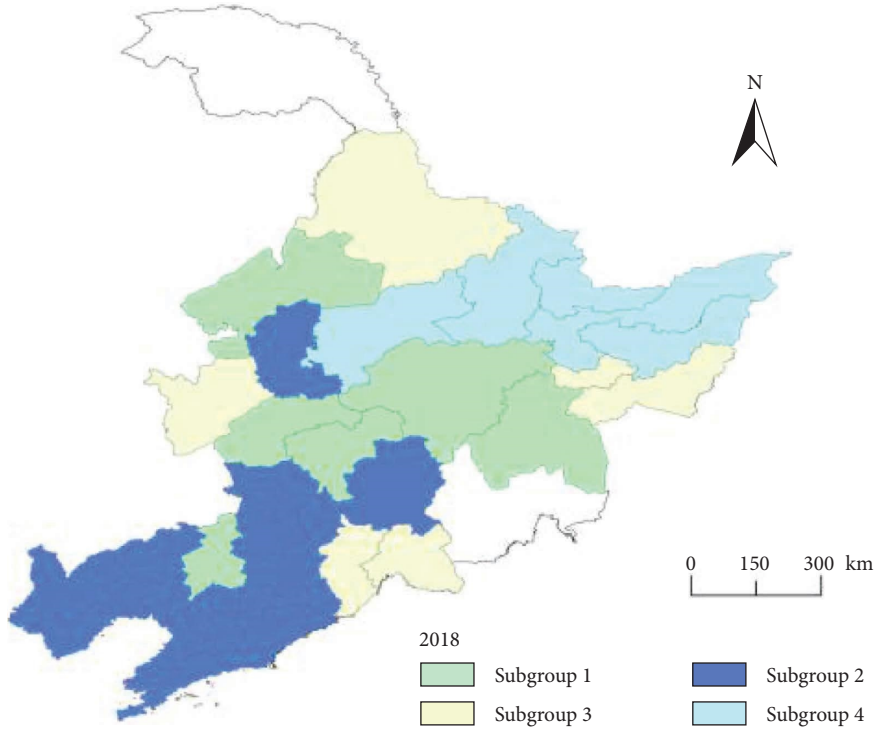

Figure 6: Condensed subgroups of urban networks.

Table 3: Density matrix of cohesive subgroups of urban collaborative networks.

Subgroup	2008				2018			
	1	2	3	4	1	2	3	4
1	0.525	0.1	0.150	0	0.975	0.725	0.125	0.425
2	0.150	0.850	0	0	0.875	0.900	0.900	0.225
3	0.125	0.300	0.450	0.025	0.600	0.050	0.125	0.050
4	0	0	0	0.075	0.725	0.200	0	0.700

proposed in the national 14th Five-Year Plan is relatively consistent with the conclusion of this paper. Particularly, arguments in favor of the creation of the Liaoning coastal economic belt have begun to weaken and are being replaced with the unified planning, construction, and development of the entire Liaoning province.

(3) The environmental security pattern of the region was constructed with Subgroup 3 as the core. Subgroup 3 includes the cities of Heihe, Shuangyashan, Jixi, Baicheng, Tonghua, and Baishan, which are located in the southeast, northwest, and southeast of the three northeastern provinces. They are also important ecological barrier areas and ecologically vulnerable areas in northeast China. Therefore, the six cities in Subgroup 3 were taken as the core to build an important ecological space in the three northeastern provinces, create an ecological barrier with interprovincial linkage and green economy priority, and jointly explore and promote a new path of ecological priority and green development.

(4) We construct a new development highland in northeast Heilongjiang province with Subgroup 4 as its core. For a long time, the northeast of Heilongjiang Province has been excluded from both the former industrial corridor of Harbin, Daqing, and Qi and the current urban agglomeration of Harbin and Changsha. According to our findings, only four concentrated subgroups were identified. Heilongjiang exhibited convergent synergy in the northeast and the urban division of labor was clear, the Sanjiang Plain was characterized by its food production, Yichun and Suihua possess forest tourism resources that must be further developed, and there is a transformation of the coal industry in Hegang. Furthermore, there are multiple opportunities for development and trade near the Russian border.

6. Conclusion

(1) The spatial structure of the coordinated development capacity of cities in the three northeastern provinces presents a three-level circle structure consisting of core cities and peripheral cities, where the core cities are the most developed and interconnected. Moreover, the synergy development capacity of these cities was further polarized with Harbin, Changchun, Shenyang, and Dalian as the core, as this further concentrated the synergy ability of the cities in this region.

(2) The urban collaborative network density in the three northeastern provinces increased significantly. The

network density in the three northeastern provinces was 0.128 in 2008 and reached 0.489 in 2018. A pattern of coordinated urban development in the three northeastern provinces of China is gradually forming. However, the intercity connection has not weakened due to the decline of urban coordination capacity. The collaborative network of cities in the three northeastern provinces is further extended to the north. Most cities in Liaoning Province, Jilin Province, and Heilongjiang Province gradually established collaborative development relations with other cities, and transprovincial and transregional cooperation models were gradually formed. From 2008 to 2018, the overall level of urban intermediary centrality in the three northeastern provinces showed a downward trend, indicating that the coordinated development of cities does not require a third city to connect them. Instead, any two cities can establish direct links, and the development of the three northeastern provinces tends to be coordinated.

(3) We reconstruct the Harbin-Yangtze urban agglomeration. To construct the spatial development pattern of Liaoning Province and carry out unified planning, construction, and development in Liaoning Province. With Heihe, Shuangyashan, Jixi, Baicheng, Tonghua and Baishan cities as the major cities, to build an important ecological space in the three northeastern provinces, create an ecological barrier with interprovincial linkage and green economy priority, and jointly explore and promote a new path of ecological priority and green development. Northeast Heilongjiang Province has the convergence of collaborative ability and the clear division of urban functions, so as to build a new development highland in northeast Heilongjiang Province.

Data Availability

The data are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (41301172), Youth Innovative Talents Training Program of Ordinary Undergraduate high Schools in Heilongjiang Province, (UN-PYSCT-2017193 and UN-PYSCT-2017184), doctor starting fund project of Harbin Normal University (XKB201815), and postgraduate innovation research project of Harbin Normal University (HSDSSCX2021-25).

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