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Research on Chengdu-Chongqing Urban Agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area Innovation Network Structure

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Abstract: Under the background of factor-driven to innovation-driven, urban innovation is very important in the regional development pattern.In this paper, Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area are taken as the research objects. Based on the co-authored data of papers among cities, a theoretical knowledge innovation network is constructed.With the help of social network analysis method, the overall characteristics and network centrality are compared and analyzed, thus revealing the development status of Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area knowledge innovation network.The empirical research shows that: (1) During the research period, the overall density and agglomeration capacity of Guangdong-Hong Kong-Macao Greater Bay Area theoretical knowledge innovation cooperation network are higher than those of Chengdu-Chongqing urban agglomeration. (2) Dual-core cities Chongqing, Chengdu, Guangzhou and Shenzhen have significant innovation polarization effects.

Keywords: Guangdong, Hong Kong and Macao urban agglomeration; Chengdu-Chongqing urban agglomeration; Innovation network; Social network analysis.

1. Introduction

1.1. Research background and significance

Under the background that the driving force of global economic growth is changing from "factor-driven" to "innovation-driven", innovation is the key to determine the future development direction of the region, and how to lead development through innovation is a topic worthy of attention [1]. Under the global mobile space, the emergence of urban agglomeration is the inevitable result of the development of knowledge economy and knowledge flow. At present, the world economic competition has developed to the stage of urban agglomeration competition. As the main regional innovation system, the development of urban agglomeration can realize the optimal allocation of resources across cities in a wider range, and at the same time, it will promote the development of cities within the urban agglomeration with spatial spillover effect. The rise of urban agglomeration has become the most prominent feature of regional development in China in recent years.

1.2. Literature review

At present, the research of innovation network mainly focuses on three aspects: ①the construction of innovation network relationship. A large number of scholars have built a knowledge innovation cooperation network by studying the data of joint patent applications [2] [3] [4]. At present, some scholars in academic circles also use the data of co-authored papers to build an innovation cooperation network and explore the evolution of the network[5] [6]. In addition, a few scholars consider the integration of scientific or technical knowledge in the research of innovation network, and discuss the innovation cooperation network from the dual perspectives of technical cooperation and scientific cooperation [7] [8]. ② Innovating the characteristics of network structure. With the continuous innovation of theoretical research and methods, social network analysis methods have been widely used to explore innovative networks, thus revealing the complex structural characteristics of innovative networks and obtaining rich research results [9]. Early research mainly focused on the structure of innovation networks within regions. With the wave of globalization, more scholars began to focus on cross-border innovation links between regions, and innovation networks presented certain regional forms and spatial characteristics. ③ Spatial-temporal evolution of innovation network. The evolution of innovation network, as an important topic discussed by economic geographers[9], refers to the change of organizational form and structure of innovation network caused by the constant adjustment of cooperation mode among innovation subjects in order to cope with the unpredictable internal and external innovation environment. The rise of the concept of proximity enriches the research content of network evolution. BOSCHMA(2005) [11] theoretically divides proximity into five dimensions: geographical proximity, cognitive proximity, social proximity, institutional proximity and organizational proximity. With the continuous development of research, this classification system has been widely used in the research of innovative networks [12][13].

To sum up, looking at the existing research at home and abroad, although we have achieved fruitful research results, there are still the following problems: the research on innovation network is mainly based on industrial clusters, enterprises, Industry-University-Research and urban agglomerations, and the existing literature is relatively lacking in comparing Chengdu-Chongqing urban agglomeration with Guangdong-Hong Kong-Macao Greater Bay Area. Therefore, by comparing and analyzing the urban agglomerations with relatively backward development level and the urban agglomerations with relatively high development level, based on the co-authored papers, we can deeply study the outstanding problems in the development of

Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area innovation network, with a view to providing effective reference for improving their overall innovation ability.

2. Research Methods and Data Sources

2.1. Data sources

Drawing lessons from previous studies [14], the data time span is set from 2012 to 2022, because since 2012, with the introduction of a series of scientific and technological innovation policies, the innovation capabilities of cities in urban agglomerations have been significantly improved, and the innovation cooperation between cities has shown explosive growth. Based on the Web of Science core collection database [15], the authors in two cities are selected side by side through advanced search, and the published co-authored papers are obtained to represent their theoretical knowledge innovation level.

2.2. Research methods

At present, scholars at home and abroad mainly use social network analysis, SNA) to reveal the innovation network structure and evolution from multiple angles. Social network analysis method uses comprehensive graph theory, probability theory and geometric mathematics to reveal the structural characteristics of the network and the complex relationships formed among individuals from different angles and levels [16]. Therefore, this paper uses social network analysis to explore the node relationship and network structure of knowledge innovation network between Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao-Greater Bay Area urban agglomeration, and mainly analyzes the overall network characteristics and network centrality topological indicators.

3. Empirical Analysis

3.1. Chengdu-Chongqing Urban Agglomeration and Guangdong-Hong Kong-Macao Urban Agglomeration Innovation Network Features

(1) the overall characteristics of the innovation network

In this paper, the network density and clustering coefficient of innovation networks of Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao urban agglomeration are measured by UCINET software, and the specific results are shown in Table 1, from which the overall network characteristics of innovation networks of Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao urban agglomeration are obtained.

Table 1. Overall Characteristics of Chengdu-Chongqing Urban Agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area Innovation Network

	Chengdu-Chongqing urban agglomeration	Guangdong-Hong Kong-Macao Greater Bay Area
network density	0.1833	0.2091
Clustering coefficient	0.664	0.778

First of all, from the network density value, the network density in Guangdong-Hong Kong-Macao Greater Bay Area is relatively high, and the phenomenon of innovation association is relatively common, which shows that the knowledge innovation links among cities in the Bay Area are relatively close, and innovation interaction is frequent. Although Chengdu-Chongqing area has established innovation cooperation links, there is still much room for improvement. From the network agglomeration coefficient, Guangdong-Hong Kong-Macao Greater Bay Area is higher than Chengdu-Chongqing urban agglomeration, which shows that the knowledge innovation cooperation network in the Bay Area shows strong agglomeration, and the network connection efficiency and accessibility are high, while the cluster coefficient value in Chengdu-Chongqing area is low, indicating that there is still much room for improvement.

(2) Analysis of the network centrality of innovation networks

Based on the differences in development endowments and innovation environments of cities, in order to further reveal the position and role of network nodes in the network, this paper selects three different types of center positions: degree centrality, near centrality and intermediate centrality. Through the Centrality module in UCINET software, the centrality indicators of Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area innovation network are calculated, as shown in Table 2.

Specifically, in terms of degree centrality, contrary to people's cognition, Chongqing and Shenzhen, which have high innovation ability, have low extroversion centrality and high introversion centrality. It can be seen that cities with high innovation resources have not had a strong innovation-related impact on other cities, but have obtained high innovation-related benefits from other cities. This may be because cities with high innovation potential can attract the inflow of innovation elements, and with the evolution of time, there will be the Matthew effect of "the strong will remain strong". Although this development mode with agglomeration trend will make a few cities in the urban agglomeration develop into innovative cities in the short term, in the long run, this development trend will inevitably widen the innovation development gap among cities in the urban agglomeration [17], which is prone to the trend of "the stronger the stronger". Different from Shenzhen and Chongqing, Chengdu and Guangzhou, two provincial capital cities, have high degrees of openness and openness, which indicates that the innovation behavior of these two cities will have an impact on relatively many other cities' innovation activities, and the spillover effect on other cities is more obvious. Cities such as Ya 'an, Zhaoqing and Jiangmen are due to low innovation potential, limited R&D resources, and limited industrial structure and geographical location, resulting in low networking level and weak links in foreign cooperation and exchanges.

Table 2. Central analysis of theoretical knowledge network

City	DEGREE CENTRALITY		CLOSENESS CENTRALITY		BETWEENNESS CENTRALITY
	NrmOutDeg	NrmInDeg	outCloseness	inCloseness	
Chongqing	13.333	100.000	8.242	100.00	2.302
Chengdu	26.667	100.000	8.33	100.00	12.778
Zigong	20.000	6.667	8.982	6.667	0.159
Luzhou	13.333	26.667	8.242	57.692	0.00
Deyang	26.667	0.000	9.036	6.25	0.00
Mianyang	13.333	33.333	8.242	60.00	0.00
Suining	33.333	0.000	9.091	6.25	0.00
Neijiang	13.333	0.000	8.929	6.25	0.00
Leshan	13.333	0.000	8.929	6.25	0.00
Nanchong	13.333	26.667	8.242	57.692	0.00
Meishan	13.333	0.000	8.929	6.25	0.00
Yibin	13.333	0.000	8.929	6.25	0.00
Guang'an	20.000	0.000	8.982	6.25	0.00
Dazhou	20.000	0.000	9.804	6.25	0.00
Ya ' an	13.333	0.000	8.929	6.25	0.00
ziyang	26.667	0.000	9.036	6.25	0.00
Guangzhou	40	100	14.286	100.00	26.111
Shenzhen	20	80	13.889	83.333	3.333
Hong Kong	20	30	13.889	58.824	0.556
Macao	20	0	15.873	9.091	0.00
Foshan	20	10	13.889	52.632	0.00
Zhuhai	20	10	13.889	52.632	0.00
Huizhou	20	0	15.873	9.091	0.00
Dongguan	20	0	15.873	9.091	0.00
Zhongshan	10	0	15.625	9.091	0.00
Jiangmen	20	0	15.873	9.091	0.00
Zhaoqing	20	0	15.873	9.091	0.00

For the degree of proximity, all cities in the innovation network have a low degree of proximity. From the analysis of inward approach centrality, it is found that the cities with high penetration in Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area innovation network also have high penetration. In the theoretical knowledge network, from the perspective of each city node, cities such as Chongqing, Chengdu, Guangzhou, Shenzhen and so on rank higher than the out-of-point index, which shows that these cities are good at benefiting from more cities in the innovation network and are easy to drive the further development of regional innovation networks. Compared with Chongqing, Chengdu and Guangzhou, it has a close penetration rate of 100, more resources and advantages, and outstanding independent innovation ability. The penetration rate of Shenzhen, the other polar core of Guangdong-Hong Kong-Macao Greater Bay Area, in the network is lower than that of Guangzhou, indicating that it is not easy to be controlled by other cities in the process of benefiting from the innovation influence of other cities. On the contrary, most cities with low degrees of prominence also have low degrees of proximity, such as Guang 'an, Dazhou, Jiangmen, Zhaoqing and other cities, which shows that although these cities have high independence in the regional innovation network and are not easily influenced by other cities, they can only obtain innovative benefits from fewer cities, so these cities urgently need to enhance their innovative profitability potential in the innovation network.

As far as the intermediate centrality is concerned, there is a serious polarization between Chengdu-Chongqing urban agglomeration and the cities in Guangdong-Hong Kong-Macao Greater Bay Area Innovation Network. Chongqing, Chengdu, Guangzhou and Shenzhen are at the top of the total list in the theoretical innovation network, indicating that these cities are in the "middleman" position in the innovation network and have high control over the information resources of other cities. However, in other cities, the value of this index is mostly 0, indicating that it is at the edge of the knowledge network and cannot grasp the resources in the network. From this point of view, the development of intermediary centrality presents an unbalanced situation. On the one hand, the higher the level of the city, it will produce knowledge radiation and establish knowledge links with other cities; On the other hand, because some marginal cities are in a weak position and have strong dependence on other cities, it is not conducive to benign interaction between them.

4. Conclusions and Recommendations

4.1. Research conclusion

The study area of this paper is Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area, and the theoretical knowledge network is constructed by using the data of co-authored papers. Using social network analysis method, this paper explores the characteristics of innovation network structure changes in Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao urban agglomeration, and draws the following conclusions:

(1) From the overall network structure, the overall density and agglomeration capacity of Guangdong-Hong Kong-Macao Greater Bay Area is higher than that of Chengdu-Chongqing urban agglomeration, and the knowledge innovation cooperation is more closely linked. The efficiency

and accessibility of innovation cooperation in cities are higher.

(2) From the perspective of network centrality, Chengdu-Chongqing Urban Agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area's innovation network both have a bipolar model. The four node cities of Chongqing, Chengdu, Guangzhou and Shenzhen have formed obvious polarization centers, and gradually developed into the spatial pattern of central cities supported by Chongqing, Chengdu, Guangzhou and Shenzhen, with the typical growth characteristics of "the stronger the stronger". However, the performance of these four node cities in their respective urban agglomerations is different.

4.2. Policy recommendations

Based on the above research, the following suggestions and thoughts are provided to promote the development of Chengdu-Chongqing urban agglomeration and Guangdong-Hong Kong-Macao Greater Bay Area innovation network:

(1) Core cities should strengthen the role of radiation, cultivate and expand new kinetic energy, and promote knowledge spillover and knowledge creation. As the core node cities of Chengdu-Chongqing urban agglomeration, Chengdu and Chongqing need to strengthen the function of innovation hub, accelerate the flow and agglomeration of innovation elements, strengthen the interaction between the two circles, and lead the economic development of urban agglomeration. Guangdong-Hong Kong-Macao Greater Bay Area should strengthen the central position of Guangzhou and Shenzhen, give full play to the radiation supporting role of the strong alliance between Guangzhou and Shenzhen, realize high-level interconnection and consolidate the key axis of Greater Bay Area's innovation network.

(2) Through the implementation of relevant systems and policies, we will promote the construction of more central cities, promote the development of regional integration, give play to the advantages of two-way contact, and stimulate the vitality of innovative subjects in the region. Chengdu-Chongqing Urban Agglomeration adheres to the thinking of "Sichuan-Chongqing chess game", cultivates and develops new nuclear level from point to area, integrates and optimizes regional resources, fills in key shortcomings, and significantly enhances the overall competitiveness of the region. Guangdong-Hong Kong-Macao Greater Bay Area will build a spatial pattern of pole-driven networking, optimize the policy environment, market environment and economic environment, promote the in-depth cooperation among cities in Guangdong-Hong Kong-Macao Greater Bay Area in scientific and technological innovation, financial services and infrastructure, and realize the complementary functions among cities, so as to help create more innovative growth poles.

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