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NETWORK MEASUREMENT, PLATE RECOGNITION AND INTRA-REGIONAL COLLABORATION OF INNOVATION SPATIAL ASSOCIATION AMONG CITIES

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Abstract
Accurately identifying the regional innovation spatial association network formed by the inter-regional innovation diffusion is conducive to promoting the rational allocation of innovation resources and improving the efficiency of regional collaborative innovation. Based on the modified gravity model to determine the innovative space association relation matrix, the characteristics and evolution of the inter-city innovative space association network in Guangdong province from 2006 to 2018 were analyzed by social network. During the sample investigation period, the density of the provincial innovative space associated network first decreased and then increased. On the whole, the innovation associated and spillover effect among cities were relatively obvious, but the structure of the inter-city innovative space network was relatively strict. The innovation space correlation network of the whole province presents an unbalanced situation, with obvious core-edge structure. Guangzhou and Shenzhen drive the formation of regional collaborative innovation pattern. Guangzhou, Shenzhen, Zhuhai and Foshan are in the "net benefit" sector, the peripheral cities of the Pearl River Delta are in the "broker" sector, and the cities in the east and northwest of Guangdong are in the "net spill" sector. Finally, it puts forward some Suggestions on regional coordinated development strategy to enhance independent innovation ability.
Keywords:regional innovation network; spatial network characteristics; network plate identification; collaborative innovation strategy

1 INTRODUCTION

In the 21st century, science and technology revolution and industrial revolution booming, driver development strategy for the implementation of the innovation, science and technology investment in basic research in recent years in China are going up, the original innovation ability development, but the integrated innovation, the introduction of digestion, absorption and innovation ability are relatively backward, which restricts the further improve the ability of independent innovation of China. With the continuous development of regional economy, individual innovation limited by limited resources in the region is more and more unable to meet the needs of regional innovation. Therefore, inter-regional innovation diffusion and the resulting regional innovation network become a new perspective for research on improving the level of regional innovation[1]. Regional innovation networks, with their innovation, openness, embeddedness and synergy, have become the key to maintaining regional sustainable innovation capability[2][3]. So it is necessary to strengthen the research on innovation diffusion and regional innovation network in order to break through the innovation bottleneck, strengthen collaborative innovation of regional network, and further enhance regional independent innovation capability.

Only through innovation diffusion can technological innovation promote the creation of regional innovation network subject collaborative innovation. Therefore, the innovation diffusion mechanism and its level should be analyzed in order to study regional innovation network in depth. In the traditional technology innovation diffusion system, the city or government is mainly located in the channel layer in the system and builds the bridge of innovation diffusion for enterprises, scientific research institutions or individuals at the diffusion source layer and the adopter layer[4].However, on the macro level, the theory of innovation spatial diffusion points out that local actors can also become the diffusion and acceptance units of innovation resources in the innovation diffusion mechanism[5].After the innovation comes into being in the central city, it spreads to the peripheral city along the city level gradient. Meanwhile, the innovation ability of different levels of cities overlaps, and the inter-city innovation spatial association network emerges accordingly. At present, Based on the innovation diffusion system, Chinese scholars have conducted in-depth studies on the innovation diffusion mechanism of the industry-university-Research innovation network at the medium and micro level and the innovation diffusion mechanism in the industrial cluster innovation network. On the contrary, the academic circle pays relatively

insufficient attention to the macro-inter-city innovation spatial correlation network. Secondly, determining the inter-city correlation relationship is the key to the construction of urban spatial correlation network. Currently, the academic circle mostly USES the gravity model based on geographical proximity to determine the urban innovation correlation relationship to build the regional innovation spatial correlation network. In fact, the concept of multidimensional proximity points out that although geographic proximity can influence the structure of innovative spatial association network by influencing the flow of innovative resources, other adjacency dimensions can also become the key to the establishment of innovative association relationship[6].As for the inter-city innovation spatial association network, it is easier to establish and maintain the collaborative innovation relationship between two cities with high social proximity. However, when the social gap between cities is large, the innovation resources exported by one city to another city cannot meet the actual innovation needs of the latter. Therefore, only when the geographical proximity and social proximity are fully considered in the gravity model, can the innovative spatial association between cities be judged more accurately and the innovative spatial association network among cities be constructed.

At present, Chinese scholars pay more attention to the innovation spatial association network between major cities in China and the Yangtze River Delta, but less attention to the regional innovation network research in Guangdong province, a big innovation-oriented province. As national innovation field vanguard, Guangdong has for three consecutive years in the Chinese regional innovation ability assessment report in the country's first (by 2019), but the regional economic development and the innovation resource distribution imbalance situation is still present, promoting regional synergy innovation should be in addition to improve the ability of original innovation of another focus in the field of science and technology innovation in Guangdong province. In view of this, this article in considering geographical proximity and a city on the basis of the social proximity of the event in Guangdong province were measured with modified gravity model innovation space correlation and correlation matrix were determined, through the social network analysis method to network density, network, relational, network level degree of multiple dimensions, such as Guangdong province innovation space relevance network overall characteristics; The status and function of each urban node in the innovative spatial association network are reflected by three centrality indexes. On this basis, the block model analysis is carried out to reveal the urban spatial clustering and the flow of innovative resources between the plates. Based on the perspective of multi-dimensional proximity, this paper more accurately depicts the inter-city innovation correlation relationship and the innovation space correlation network of Guangdong Province, and interprets the three levels of technology innovation diffusion system from the macro level, so as to provide the theoretical basis and basis for Guangdong province to formulate science and technology innovation policies and promote regional collaborative innovation.

2 LITERATURE REVIEW

2.1 Innovation diffusion and Regional Innovation network

The accumulation of regional innovation is mainly realized by means of individual technological innovation within the region and innovation diffusion between regions. Along with knowledge spillovers, inter-regional innovation diffusion can improve the knowledge supply of neighbors without increasing the regional cost[7][8]. Therefore, in a sense, innovation diffusion is more important than self-innovation[9].The early academia mainly focused on the diffusion rate of innovation in macro and micro aspects. With the continuous development of information technology, the relationship between innovation subjects became increasingly close, and scholars began to pay attention to the research on innovation diffusion in complex social networks[10].The four elements of innovation diffusion -- innovation, time, communication channels and social system -- emphasize innovation as an integration process, and the process of knowledge spillover and reception between the internal subjects of the system is very critical. Therefore, the research on innovation should shift its focus to regional innovation network[6][11].In regional innovation network, individual innovation resources become innovation resources among network members through innovation diffusion, network members begin to have common interests and interdependence, the use efficiency of innovation resources owned by a single member is greatly improved, making the innovation function of regional innovation network greater than the innovation function of a single member.

Think technology innovation diffusion system model, the system consists of diffusion layer, access layer and adopters, including scientific research institutions, enterprises or individuals in the diffusion layer and adopters, innovation resource provider and receiver of roles, and a government or city at channel level mainly to provide specialized services to the innovation main body, do not assume the output or input of innovation resources function[4].At the same time, the first qualitative study also think about regional innovation networks, regional innovation network by area related enterprises, scientific research institutions, etc, is can produce synergies between main body in the system of forms of cooperation[12] [13], so the community initially from micro level of production, innovation network and delve into industrial cluster innovation network. Along with the gradually thorough research, scholars have found that both production, innovation network and industrial cluster innovation network, the network

in the study were assumed in the individual regional innovation system, there is no space correlation, therefore, combining with the spatial diffusion of innovation theory, academic circles in recent years, more emphasis on the analysis of the regional innovation network on a macro level. According to Hagerstrand's three-stage innovation space diffusion theory, innovation diffusion is related to city level: firstly, it spreads from the main city to the secondary central city, and then to the surrounding cities of the secondary central city[14].Under this influence, in the 1960s and 1970s, the academic circle closely linked the urban system with the innovative spatial diffusion theory and carried out a lot of research, and built the urban diffusion model based on the theory of nearest neighbor effect and class effect[15][16]. However, after that, the relevant research gradually decreased. Since the 21st century, in Smith after the space of innovation diffusion model is established based on the spatial correlation[17], based on the existing city between innovation diffusion theory and related space model, European scholars to European regional innovation space is a lot of empirical research on relation network, such as Cantner patents based on cooperation in Germany[18] study regional innovation network; Fischer et al. conducted an empirical analysis on the spatial correlation of knowledge flows between regions in the European Union through the number of patent cooperation[19].

In order to implement the innovation-driven development strategy, the 13th Five-Year National Science and Technology Innovation Plan clearly states that in order to build an efficient and coordinated national innovation system, it is necessary to build an open and coordinated efficient innovation network centering on getting through the channel between science and technology and economy. And specific to the regional innovation network, the outline of national innovation driven development strategy should emphasize cross-regional integration of innovation resources, build a cross regional innovation network, maintain regional innovation elements connectivity, promote Beijing-Tianjin-Hebei, Yangtze river delta economic zone, and other countries strategic regional innovation ability, create regional synergy innovation community. In the new century, China's academic circle has also intensified its research on the theory of innovation spatial diffusion, focusing on exploring the spatial correlation mechanism between city level and innovation diffusion elements[20][21].Under the policy and academic background, combined with the existing research abroad, the domestic scholars in recent years, using the spatial econometric analysis technology to prove that China's regional innovation exists significant spatial correlation, and a regional innovation output depends on the spatial characteristics of commensurate with similar in other parts of the innovation input and output of[22], the resulting regional innovation diffusion significant positive impact on regional economy[23].In view of the important significance of innovation diffusion to economic development, the academic circle began to strengthen the research on the spatial correlation network of regional innovation in China. For example, based on the number of joint patent applications, The empirical research of Gong Zhigang proved that the network indicators of China's cross-regional technology innovation cooperation network had a good development trend[24].Zhang Jingshuai et al. investigated the county innovation network of Zhejiang Province based on the regional innovation capability index[25]. Hu Yan et al. used Granger causality test to determine the innovation correlation between cities in the Yangtze River Delta and build the innovation spatial correlation network of cities in the Yangtze River Delta[26].

2.2 Determination of spatial correlation of regional innovation

Whether or not the network nodes are connected and the strength of the connection will affect the regional network structure. Therefore, how to accurately determine the regional innovation spatial association relationship is the key to construct the regional innovation spatial association network. Relationship dimension is an important dimension of social network analysis. In fact, another dimension of social network analysis, namely structure dimension, pays attention to the distribution of relations between nodes and is also inseparable from "relationship"[27] .Early research on regional innovation network is mainly using Moran index and Gini coefficient of innovation measurement space correlation degree, and based on the cooperative patents to establish urban spatial correlation between innovation, but Moran index and Gini coefficient to pay more attention to the overall network structure rather than the relationship attribute, unable to determine the actual circumstances of the internal relationship between the nodes[21], patents and cooperation can reflect the innovation cooperation between the two cities, but neglected the individual city innovation ability, therefore academic start will be widely applied in the field of trade gravity model into the regional innovation network to determine urban spatial correlation between innovation. The gravity model pays more attention to the dimension of network relations rather than the dimension of structure. At the same time, it can judge the innovation correlation between cities based on the comprehensive consideration of the innovation ability of cities and the geographical distance between cities, and it can reflect the internal characteristics of the network more clearly. Maggioni and so on for the first time introduced the gravity model between investigation to determine the regional innovation network correlation matrix, prove that geographic distance is still decided the main factors of regional knowledge flows[28], in recent years, Chinese scholars also began to use gravity model to explore the urban network of innovation space correlation between, gravity model is widely used in the field of innovation in our country at the same time also is able to continuously modified to enhance applicability. Based on the classification of knowledge flow as origin and destination, innovation space associated network nodes assume the function of receiving as well as innovation overflow, so the

association relationship between network nodes is directional. In order to construct a directed matrix, the academic circle introduced a correction index into the gravity model to judge the spillover and reception of individual innovation, and set a threshold to obtain a binary matrix, so as to determine the true direction of inter-regional innovation flow[29][30].

Throughout the existing literature research, this article found that the following two points: first, look from the object of study, the research focus in China's regional innovation space associated network within the scope of the major cities or the Yangtze river delta urban agglomeration between innovation network, and the national innovation frontier city of Guangdong province to explore correlation between innovation space network dynamics. In regional innovation ability constantly improve at the same time, also clearly aware of its regional economic development in Guangdong province and the innovation resource distribution trend of equalization, the people's government of Guangdong province in 2019 "file" number one "some policy measures on further promoting the scientific and technological innovation" also explicitly request to improve regional innovation development balance coordination. But the related research still pay more attention to regional innovation ability evaluation and urban space system in Guangdong province, for the intercity association studies innovation space is insufficient, only to clarify the relationship between innovation ability in order to further strengthen city Guangdong province regional collaborative innovation, promote Guangdong regional innovation ability, therefore to the Guangdong province international innovation space associated network so it is urgent to build and analysis; Second, from the perspective of research methods, existing researches only consider the influence of geographical distance on relationship establishment when using gravity model to measure the spatial association relationship of regional innovation, but do not include economic distance. Geographic proximity is conducive to innovation to strengthen communication between individuals to speed up the flow of innovation resources, but according to the theory of multidimensional proximity, affect the efficiency of regional innovation system not only geographical proximity, social proximity can also through the establishment of trust relationship and promote tacit knowledge transfer[5], and the empirical study proves that the geographical characteristics and social and economic characteristics will impact on China's regional innovation spatial correlation, which comes from the influence of social and economic characteristics of the larger[19].Therefore, in the construction of gravity model, the influence of multi-dimensional proximity on the construction of innovative spatial association can be accurately reflected only when both geographical factors and socio-economic factors are included. In this paper, economic factors are incorporated into the gravity model as an index reflecting social proximity to determine the true distance between cities, so as to judge the spatial correlation of inter-city innovation more accurately.

3 MEASUREMENT METHOD AND INDEX CONSTRUCTION OF INTER-CITY INNOVATIVE SPATIAL NETWORK CORRELATION IN THE REGION

3.1 Measurement of innovation spatial correlation

In the original literature, the number of patent applications in the region was mainly used to measure the regional innovation ability when using a single index. In order to reduce its non-equilibrium, this paper used the number of patent applications per 10,000 people to measure the regional innovation ability. In order to determine the connection of regional innovation, this paper refers to the modified gravity model applied in the field of energy consumption by Liu Huajun et al.[31], and proposes the following gravity model applicable to the field of regional innovation cooperation:

$$x_{ij} = k_{ij}\frac{\sqrt{G_i P_i}\sqrt{G_j P_j}}{\left(\frac{D_{ij}}{g_i - g_j}\right)^2},\quad k_{ij} = \frac{P_i}{P_i + P_j} \tag{1}$$

In equation (1), i and j represent cities; x_{ij} represents the attraction of innovation cooperation between city i and j; G_i、G_j represents the GDP of cities i and j; P_i、P_j represents the number of patent applications per 10,000 people in representative cities i and j; D_{ij} represents the geographical distance between city i and j; g_i、g_j represents the per capita GDP level of cities i and j; k_{ij} represents the contribution rate of city I in the innovative connection between i and j. Compared with the original model which only considers geographical distance, the revised gravity model $\left(\frac{D_{ij}}{g_i - g_j}\right)^2$ comprehensively considers the actual economic and geographical "distance" between the two cities. At the same time, in view of the asymmetric characteristics of regional innovation correlation, this paper introduces the coefficient k_{ij} to modify the gravitational constant, and judges the real flow direction of innovation resources through the relative position of a city in a pair of "relationships", and obtains the gravity matrix from the modified gravity model. At the same time, in order to eliminate the impact of weak relationship on the integrity of the network, the average value of each line is taken as the critical value. When x_{ij} is greater than or equal to the

threshold, it indicates that the correlation strength of city i and j is large, denoting as 1.When x_{ij} is less than the average value, it is denoted as 0, indicating that there is no innovation spatial correlation between city i and city j, so as to obtain the binary matrix.

3.2 Feature index of innovative space network

Social network analysis method, this paper from the whole network, each node network characteristics and the block model analysis of the three parties in the face of the Guangdong province international innovation space relation network, quantitative analysis of each node, each plate and clear and comprehensive understanding of the overall network (relevant network index calculation formula in reference[32]).

Overall network characteristics. Since the overall network scale is fixed (21 prefecture-level cities), this paper explores the characteristics of the overall network with the indexes of network density, network correlation degree, network hierarchy degree and network efficiency. The network density is used to reflect the closeness of the innovation space associated network. The higher the network density, the more connections there are in the innovation space associated network, the more connections there are in the inter-city innovation space, and the closer the innovation cooperation within the province. The network correlation degree is used to represent the robustness degree of the network. If the network relies too much on a certain node city, the network will show very low robustness and may collapse quickly after the node is removed. The network hierarchy reflects the hierarchical structure of regional innovation cooperation network. The higher the network hierarchy is, the more rigid the network hierarchy is and the less smooth the flow of innovation resources is. The network efficiency is used to reflect the flow efficiency of innovation resources in the network. The lower the network efficiency, the more non-redundant connections within the network, and the better the network stability, more innovation resources will flow among the cities through the innovation spatial association network.

Network characteristics of each node. The features of each node network are represented by three types of centrality, namely degree centrality, intermediate centrality and proximity centrality. Among them, degree center is used to find the "central figure" in the innovation spatial association network. The higher the degree value is, the more innovative connections the corresponding node city has with other cities, and the more likely it is to become a central city. Degree center only reflects the power of the node, while the degree of middle center reflects the ability of a node city to control the innovative connection between other cities. The greater the degree of middle center, the stronger the control ability of the node to other nodes. Proximity to the center is used to reflect the ability of a node city to directly establish innovative spatial connections with other node cities. The greater proximity to the center is, the more the corresponding node can establish direct connections with more cities without fear of being controlled by other cities.

Block model analysis. In this paper, block model is used for spatial clustering analysis to vividly describe the plate composition in the network and the specific flow direction of innovation resources among the plates. Based on the research of Shao Hanhua et al.[33] and the reality of innovation space association network in Guangdong Province, this paper divides network members into three types of innovation and development plates. The second is the "net spill" plate, in which the number of external spillover relations of members of the plate is obvious, and the number of relations between the output of other members of the plate and their output is obvious. The third is the "broker" plate, which not only receives the self-overflow relations of other plates, but also issues the relations to other plates. When the reception and overflow relations are basically equal, the number of the external relations of plates is much larger than that of the internal relations of plates.

3.3 Data sources

This paper takes 21 prefecture-level cities in Guangdong province as the research objects. The original data involved are from Guangdong Statistical Yearbook and Guangdong Science and Technology Yearbook from 2006 to 2018. Some missing data are supplemented by statistical yearbooks of various cities. Among them, due to the absence of annual patent applications per 10,000 people in some cities, this paper calculates and makes up based on the number of population and patent applications in each city. The inter-city distance is the spherical distance calculated by ArcGIS.

4. RESULTS OF CORRELATION ANALYSIS OF INTER-CITY INNOVATION SPATIAL NETWORK IN THE REGION

4.1 Overall network structure characteristics and evolution trend

Based on the correlation matrix of inter-city innovation space determined by the modified gravity model, this paper USES social network analysis software to draw the map of inter-city innovation connection network of Guangdong province in 2018.This network is a scale-free network topology, that is, a small number of nodes have more contact with the outside world, while most of the node cities have less contact with the outside world[10].

Network density. From a numerical perspective, the maximum number of possible relationships of innovation cooperation among cities is 420, but the maximum number of actual relationships between 2006-2018 is only 105 (2007), which indicates that the connections among cities in Guangdong province are sparse and the degree of innovation space correlation is relatively low, so there is still much room for improvement in promoting in-depth innovation cooperation among cities.

Network relevance. In this paper, the relevance degree,

network hierarchy degree and network efficiency are measured to investigate the relevance of innovative spatial networks in Guangdong province. After calculation, the network correlation degree is all 1 during the sample investigation period, indicating that the innovation correlation and spillover effect among cities are relatively obvious. From 2006 to 2018, the change range of network hierarchy was small, and it remained at the level of 0.622 after 2010. The overall ranking of listed innovation spatial network was relatively high, and high network hierarchy meant relatively strict network structure, which was not conducive to the full flow of innovation elements. At the same time, with the reduction of redundant line segments, the overall efficiency of the inter-city innovative space network is on the rise. However, with the continuous improvement of network density in 2014-2018, although the efficiency of the network gradually falls down, the increase of intra-network connections improves the stability of the network, and the innovative space network of Guangdong province becomes more solid. Based on the above indicators, this paper believes that with the continuous improvement of the degree of marketization, innovation resources are more and more effectively allocated, and network efficiency also rises accordingly. However, various institutional barriers still exist in the process of innovation cooperation. Breaking down the relatively rigid spatial structure will help the innovation elements to flow more fully in the market.

4.2 Analysis of the centrality of innovative spatial networks

In this part, the position and role of cities in Guangdong province in the innovative spatial association network are considered by measuring and calculating the degree of centrality, the degree of centrality, the degree of centrality, the degree of centrality and the degree of centrality. This paper selects the data of 2018 for the report.

Degree centrality. According to Table 1, the average degree of degree center of 21 prefecture-level cities in Guangdong province in 2018 was 35.238, and 4 cities were higher than this value, ranking from highest to lowest as Guangzhou, Shenzhen, Zhuhai and Foshan. These four cities have a lot of relationships with other cities in Guangdong Province. Among them, Guangzhou and Shenzhen have connections and space overflow with 18 and 19 cities respectively, so the degree of degree center is more than 90, indicating that Guangzhou and Shenzhen occupy a central position in the innovative space association network of Guangdong Province. With the exception of Guangzhou, Shenzhen, Zhuhai and Foshan, all the other 17 prefecture-level cities have lower degrees of degree centers than average, and these cities have less innovative cooperation with other cities. At the same time, the standard deviation calculated based on the degree centers of each city in this paper is 25.236. At the same time, the degree centers of cities in the Pearl River Delta region are generally large, while the corresponding values of cities in other regions are relatively small. Larger standard deviation indicates that the city and other cities of innovation cooperation link capacity difference is bigger, may be the reason lies in the pearl river delta city's economic development level is higher, more has the ability to establish links with other cities, and the northwest of Guangdong region because of the economic scale small and remote geographical position, it is difficult to space associated with the other cities, so the three cities and other cities in less number of innovation cooperation.

Median Centrality. Measurement results according to table 1 intermediate center degree, 21 prefectural middle center degree of mean value is 3.409, higher than the value of the four cities, Shenzhen, Guangzhou, Zhuhai, Foshan, of which the center of the sum of the whole province 94.48% of the total, in particular, Guangzhou and Shenzhen center of more than 20, and the larger gap of other cities, that connect spatial correlation in the innovation network in the core position, plays the role of "mediation" and "bridge". As the planning and construction of national independent innovation demonstration zone is gradually carried out, Guangzhou, as the national innovation center city, and Shenzhen, the first national innovative city, will play a more critical role as a bridge link. Except for the above four cities, the degree of intermediate center in other cities is no more than 1, indicating that these cities are at the edge of innovative spatial association network and have little ability to control the correlation between other cities. It can be preliminarily seen that within the innovation spatial association network of Guangdong province, there is a significant gap between the center of each city, and the core-edge pattern is prominent. The establishment and development of inter-city innovation cooperation relations are largely dominated and controlled by the four cities, Namely, Guangzhou, Shenzhen, Pearl and Buddha.

Proximity centrality. The measurement results of proximity degree in Table 1 show that the average proximity degree of all cities in Guangdong province is 62.628, with Shenzhen, Guangzhou, Zhuhai and Foshan all higher than this level, indicating that these four cities have a strong ability to directly establish innovative spatial correlation with other cities and act as central actors in the spatial network. With the administrative status of provincial capitals and special economic zones and strong economic strength, the two urban centers of Guangzhou and Shenzhen are located in the geometric center of the innovative spatial association network with the degree of over 90. It is faster and more convenient for them to spill out the innovative elements or to receive the input of innovative resources from other regions. The other 17 cities have poor access to innovative resources and a high degree of external dependence. Combined with the measurement results of the centrality, they are mainly controlled by the four cities of Guangzhou, Shenzhen, Zhuhai and Foshan.

Table 1 Centrality analysis of inter-city innovation spatial association network in Guangdong Province

City	Degree Centrality				Median Centrality		Proximity centrality	
	Out-degree	In-degree	Centrality	Order	Centrality	Order	Centrality	Order
Guangzhou	5	18	90.000	2	20.272	2	90.909	2
Shenzhen	4	19	95.000	1	20.941	1	95.238	1
Zhuhai	4	14	80.000	3	14.07	3	83.333	3
Shantou	4	0	20.000	13	0.102	13	55.556	13
Foshan	5	15	80.000	3	12.345	4	83.333	3
Shaoguan	5	0	25.000	9	0.207	12	57.143	9
Heyuan	6	0	30.000	5	0.532	6	58.824	5
Meizhou	6	0	30.000	5	0.532	6	58.824	5
Huizhou	2	5	30.000	5	0.643	5	58.824	5
Shanwei	5	0	25.000	9	0.295	9	57.143	9
Dongguan	2	6	30.000	5	0.363	8	58.824	5
Zhongshan	4	3	20.000	13	0.064	20	55.556	13
Jiangmen	5	5	25.000	9	0.277	11	57.143	9
Yangjiang	4	0	20.000	13	0.102	13	55.556	13
Zhanjiang	4	0	20.000	13	0.102	13	55.556	13
Maoming	4	0	20.000	13	0.102	13	55.556	13
Zhaoqing	4	2	20.000	13	0.102	13	55.556	13
Qingyuan	3	2	15.000	21	0.029	21	54.054	21
Chaozhou	4	0	20.000	13	0.102	13	55.556	13
Jieyang	5	0	25.000	9	0.295	9	57.143	9
Yunfu	4	0	20.000	13	0.102	13	55.556	13
Mean Value	4.238	4.238	35.238	-	3.409	-	62.628	-

4.3 Identification and analysis of inter-city innovative space network plate

This paper selects the iterative correlation convergence method (CONCOR), analyzes and explores the clustering characteristics of each city in the innovative spatial association network through block model analysis, and finds out the groups in the network with relatively close connections and relatively frequent innovative cooperation. The results show that the 21 cities in Guangdong province can be divided into three parts. The first part includes Guangzhou, Shenzhen, Zhuhai and Foshan, which are the innovation centers of the Pearl River Delta and even the whole province. The second plate consists of 6 cities, followed by Dongguan, Zhongshan, Jiangmen, Huizhou, Zhaoqing and Qingyuan. Most of them belong to the relatively marginal areas of the Pearl River Delta, which are significantly driven by the radiation of the first plate. The other 11 cities become members of the third plate, Shantou, Shaoguan, Heyuan, Meizhou, Shanwei, Yangjiang, Zhanjiang, Maoming, Chaozhou, Jieyang and Yunfu, which are distributed in the eastern and western wings and the northern region.

Table 2 Spillover effect of inter-market innovation space associated plate

Plate	Total number of receiving relationships		Total number of issues		Ratio of expected internal relationships （%）	Actual internal relationship ratio（%）
	In the plate	Outside the plate	In the plate	Outside the plate		
Plate1	47	784	47	192	15	19.7
Plate2	29	293	29	238	27.5	10.9
Plate3	10	0	10	647	50	2

Table 2 measures the status of the three plates in the innovative spatial association network by the internal and external relations of the plates. The total number of spillover relations in the first plate is 239, among which 192 are plate spillover relations and 784 receive other plate spillover relations. The number of external relations received is much higher than the number of external spillover, so the first plate is the "net benefit" plate. Second plate to plate external relations, 238, received 293 links from other plate, and the proportions of the actual internal relationship between internal relationship is relatively less than expected, that already send a link to the other plate, the plate into the relationship and receive other plate, more contact with other members of the plate at the same time, that the sector as the "agent" plate; The third plate has a

huge overflow coefficient of 647, and the actual ratio of internal relations is much smaller than the expected ratio of internal relations. Therefore, the third plate is considered as a "net overflow" plate, which is constantly carrying out innovative spillover to other plates.

In this paper, the density matrix of each plate is calculated according to the overflow and reception of each plate relation. By calculation at the same time, the sample period Guangdong innovation space relevance network relationship between actual number is 1163, and the number theory possible relations is 5460 (21 x 20 x 13), so the overall network density is 0.213, this article will plate density is greater than the standard area of assignment 1, suggests that innovation is more closely associated, and the plate density is less than the overall network density value is 0, to get the plate as the matrix (see table 3).In the first plate is wide, deep, beads, Buddha four city internal contact, though there are a certain number of plates, but as a result of the four big cities at the center of innovation network of Guangdong province, to improve the level of economy and the independent innovation ability, needs to receive other plate of a large number of input of innovation resources to meet the demand of its innovation, along with the sample investigation period about innovation policy, continuous innovation infrastructure is built, prompting "siphon effect" in the produce and development between the plate and other plate; The third plate members are in Guangdong, west, north, and remote areas, because of the economic level is relatively backward, urban focus mainly on economic development, attaches great importance to the strength of the relative lack of science and technology, the insufficiency of innovation investment, combined with the innovation system mechanism still has, it is necessary to break the obstacles plate internal innovation resource flow is blocked, so the valuable resources such as the talent to external plate, significant spillover effect; Due to the long distance between the economic level and geographical location, a considerable part of the spillover innovation resources from the third plate cannot meet the new innovation demand generated by the first plate, and this part of resources instead flood into the second plate. The better geographical and economic proximity with the third plate makes the urban nodes in the second plate, as the network "brokers", more equipped with the needs and platforms to accept the input of the above resources. At the same time, the second plate also carries out innovation output and input with the first plate. The high frequency innovation space connection makes the two plates improve their independent innovation ability and promote regional collaborative innovation.

Table 3 Density matrix and image matrix of inter-market innovation space associated plate

Plate	The density matrix			The image matrix		
	Plate1	Plate2	Plate3	Plate1	Plate2	Plate3
Plate1	0.301	0.615	0	1	1	0
Plate2	0.763	0.074	0	1	0	0
Plate3	0.955	0.118	0.007	1	0	0

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the modified urban innovation cooperation gravity model, this paper calculates the innovation cooperation relationships among cities in Guangdong Province, and uses the social network analysis method to deeply explore the innovation space associated network structure of Guangdong Province and the network location of each city. The conclusions are as follows:

(1) During the sample investigation period, the density of innovation space associated network in Guangdong province decreased on the whole, but gradually increased after 2014, indicating that innovation cooperation among cities in Guangdong province is becoming more and more frequent, and more attention is paid to regional collaborative innovation while striving to improve independent innovation ability; The measurement results of relevant indexes of network correlation show that the inter-city innovation correlation and spillover effect are relatively obvious, but the inter-city innovation space network structure is relatively strict, which is not conducive to the full flow of innovation elements in the market.

(2) The innovative space correlation network of the whole province presents an unbalanced situation, with a relatively obvious core-edge structure. Guangzhou, Shenzhen, Zhuhai and Foshan (especially Guangzhou and Shenzhen) are not only in the center of the network, but also have strong ability to control and control the flow of innovative resources among the networks. Due to the lack of innovation infrastructure and other reasons, the eastern and western wings on the edge and the mountain cities in the north are difficult to establish direct links with other cities, and their external dependence is relatively high.

(3) According to the block model analysis results, Guangzhou, Shenzhen, Zhuhai and Foshan are in the first segment of the network and play the role of "net beneficiary". Due to their high level of economic development and the implementation of innovation policies, they constantly receive input of innovation resources from other segments. Dongguan, Zhongshan.Jiangmen, Huizhou, Zhaoqing, Qingyuan members belong to the second plate, as the pearl river delta is relatively peripheral cities in the "agent" role in the network, on the one hand, these cities receive

contact from members of the third sector innovation, on the other hand, with the first plate in four big cities establish two-way interactive contact, reduce network between hierarchical level, ensure the innovation resources between plate flow more smoothly; Due to the economic development level and geographical location, the "net spillovers" of urban innovation resources in the east, west and north of Guangdong have been largely spillovers, and the internal innovation links of the plates are obviously insufficient.

In this paper, the city is regarded as the subject of innovation diffusion research on regional innovation network at the macro level, and the diffusion source layer and adopter layer of technology innovation diffusion system theory are expounded from a new perspective, which is helpful to deepen the comprehensive understanding of innovation diffusion theory at different levels. In this process, this study determines the real distance between cities based on multi-dimensional proximity, providing a reference for accurately determining the innovative spatial correlation. In practice, for the Guangdong province international affiliate network building and innovation space analysis is helpful to fill the blank of the associated network of regional innovation space research in China, according to the results of the proposed "point, block, face" multi-level regional innovation space related network related policy suggestion is more advantageous to promote national strategic regional coordination ability, improve balance regional development in Guangdong province. However, this paper does not further explore the formation mechanism and influencing factors of innovative spatial correlation network in Guangdong province, and the follow-up research needs to strengthen the work in this area. At the same time, under the background of innovation spatial correlation network, urban innovation resources concentration and diffusion coexist. It is also the future research direction to study the similarities and differences of the real effects of the two on regional collaborative innovation efficiency so as to further determine the focus of innovation work in different regions.

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