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Research on the Evolution of Technological Innovation Network in China's Logistics Industry

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Abstract: Based on the basic requirements of cost reduction and efficiency increase in China's modern logistics industry and the necessity of innovation network connection, this paper uses the data of patent transfer in logistics industry from 2003 to 2021 to build the logistics industry technology innovation network based on the research paradigm of evolutionary economic geography, summarizes the development stages of China's logistics industry technology innovation based on the industrial life cycle theory, uses the social network analysis method, and analyzes the network characteristics and spatial evolution of the network from the perspective of "subject-relationship" of the network. The network characteristics and spatial evolution of the logistics industry technology innovation network in the innovation subject dimension and urban spatial network in China are analyzed from the perspective of network "subject-relationship" with the help of Ucinet, Gephi and ArcGIS software.

1. 1.Introduction

The 20th Party Congress report points out that insist on accelerating the construction of a strong network and digital China. Modern logistics industry is a composite service industry integrating transportation, warehousing, freight forwarding, information and other industries, and is a basic, strategic and pioneering industry supporting the development of national economy. With the continuous development of digital economy, the connection between various industries is getting closer and closer. Logistics industry, as a pillar industry in economic development, requires resource integration and tacit cooperation with supply chain enterprises to ultimately achieve cost reduction, increase efficiency and improve enterprise competitiveness. It can be seen that the digital transformation and upgrading in the logistics industry is also imminent. Deeply promote the efficient integration of the digital economy and logistics and transportation, while making clear and definite development plans and strategic goals for the information technology and information industry. The logistics industry is currently facing many links, difficult to monitor, weak management, container shortage, price fluctuations, uncontrollable transport plans and other factors that lead to uncertainty in the development of the industry, as well as opaque information, communication layers formed by data silos and supply chain "bullwhip effect" and other industry pain points, the urgent need for innovation-driven digital for the logistics industry transparency In this regard, it is necessary to drive the digitalization of the logistics industry to enhance the transparency, convenience and flexibility of the logistics industry, thus promoting the deepening of the digitalization of logistics.

In the current knowledge-based economy, technological innovation has long become the key to improve industrial competitiveness. Due to the complexity of technology and the high cost and uncertainty of innovation, more and more innovation agents are gradually shifting from independent R&D to cooperative innovation in order to achieve innovation resource sharing, cost sharing and risk diversification. In this regard, Freeman pointed out in 1991 [1] that innovation network is a basic institutional arrangement for systemic innovation, and the main connecting mechanism of the network structure is the cooperative innovation relationship among subjects. Since the formation of innovation network is conducive to information exchange, resource pooling and efficiency enhancement among innovation subjects, it is usually considered as an efficient innovation organization form for modern industries to cope with fierce competition. In the context of knowledge economy, the comprehensive and complex nature of innovation makes logistics innovation subjects rely more and more on external innovation resources, and tend to obtain resources and improve innovation capability through innovation collaboration, which makes single linear innovation gradually evolve into a complex innovation linkage network.

There have been studies on industrial innovation spatial networks focusing on innovation-intensive industries such as high technology, new energy vehicles and electronic information. Some scholars have explored the network characteristics of innovation-intensive industries based on cooperative patent and transfer patent data and social network analysis methods respectively, in which the important "actors" of high-tech industries have weaker control in the network structure and the cohesive subgroups mainly use the level of economic development as the cohesive criterion[2]; the innovation network of new energy automobile industry Although the scale is expanding, the overall network structure is relatively sparse[3]; the spatial distribution pattern of the electronic information industry is obvious, and the network paths change from significant localization characteristics to dynamic changes beyond geographical boundaries, and the innovation spatial network follows both the law of hierarchical diffusion and the characteristics of distance decay [4]. For the innovation network of logistics industry, many scholars analyze the characteristics, mechanism and evolution path of innovation network based on industry cluster cooperation and combined with the characteristics of logistics industry. The formation of logistics industry cluster is the external expression form of logistics service space aggregation, and innovation is the driving force of its development. Li Lanbing defined the connotation of innovation network of logistics industry, analyzed the characteristics of innovation network of logistics industry cluster, and proposed the innovation mechanism of logistics industry cluster based on innovation network [5]. Yan Liu et

al. pointed out that the innovation drive index system of logistics industry can be established from five aspects: innovation input, innovation output, innovation subject, environment base and economic benefit[6]. Guo et al. selected three influencing factors of logistics science and technology innovation input capacity, logistics science and technology innovation output capacity, and logistics science and technology innovation macro development environment, and applied factor analysis and exploratory spatial data method to analyze logistics innovation capacity by using the data of "one belt and one road" provinces[7]. Liu Yan and Sun Jie constructed a process-based "innovation input-innovation activity progress-innovation output" innovation drive model for logistics industry, and measured the innovation drive capability of logistics industry in China in the past ten years by using CRITIC-Parallel law comprehensive evaluation method[8]. Based on the network paradigm perspective, Mi Zefeng[9] and Sun Chunxiao[10] explored the spatial characteristics and driving mechanism of innovation network in logistics industry based on patent data from the spatial perspective using social network analysis and spatial measurement method, and analyzed the link between innovation network and innovation capability.

In summary, the current research on innovation network of logistics industry, scholars mainly analyze the composition and characteristics of logistics innovation network system and evolution mechanism based on industrial innovation system theory, complex network theory, resource integration perspective and other multifaceted theoretical bases from the theoretical perspective, and some scholars also analyze the innovation network of logistics industry based on social network analysis, gravity model and spatial measurement method from the perspective of innovation geography. However, the following shortcomings exist in the existing literature: First, the research mainly analyzes the characteristics, mechanisms, evolutionary paths and influencing factors of logistics industry innovation network from the theoretical perspective, and some scholars analyze the characteristics of logistics industry innovation network pattern, but the dynamic analysis of evolutionary paths and evolutionary mechanisms is insufficient; second, the research mostly focuses on equipment manufacturing industry, integrated circuit industry Thirdly, the research on existing collaborative innovation network stays at the level of single inter-enterprise collaborative innovation, inter-university collaborative innovation and inter-industry collaborative innovation, and does not integrate different subject types and relationship types from the perspective of collaborative innovation system.

In this paper, we study the evolution of logistics industry technological innovation network from multiple subjects and scales, and analyze the evolution of network pattern and overall characteristics of network structure of logistics industry innovation subjects in different types and life cycle stages from time and space scales, in order to reveal the special, dynamic and regularity of this complex innovation ecosystem of logistics industry with multiple subjects and scales.

2. Study Design

2.1. Data source and processing

Since patents are regarded as one of the most important indicators of technology level and innovation capability, this paper uses patent transfer data of logistics industry to construct a technological innovation network of logistics industry through the flow of patents among individuals, enterprises, universities and research institutes. For the search of patent data, this study combines the characteristics of logistics industry, based on the main links of logistics industry chain and supply chain, such as transportation, storage, loading and unloading, handling, packaging, distribution processing, distribution and logistics information platform, etc. The patent data search is conducted by key words on the abstract of patent specification around the products and technologies involved in the main links of logistics industry. Using the logistics industry patent assignment data, the assigned patent data was obtained from Innojoy patent database. A total of 17,670 logistics industry patent records from 2003 to 2022 were searched and downloaded, and 4,345 assignments were obtained by further screening the data with "number of assignments > 0".

This paper carries out the study of technological innovation network in logistics industry by constructing a 1-mode network. Since the network constructed by the patent transfer data is a kind of directed network, the technological innovation network of logistics industry is a 1-mode network, the rows and columns in the network matrix represent the actors from the same set, and the elements in the matrix represent the transfer relationship between the actors, the rows and columns of the matrix represent the patent subjects in the innovation network, and the matrix weights represent the number of transfers of the patent transfer data.

2.2. Research Methodology and Indicator Measurements

Since its birth, the social network analysis method has undergone more than 20 years of full development and is already a set of more than The more complete theoretical concepts and methods are widely used in various fields. The focus of the method is on the structure, the communities, organizations, markets and dynamic development, mainly for the study of the structure, dynamics and complexity of networks. Recent Over the years, with the emergence of the "evolutionary" paradigm in regional economics and economic geography, the social network analysis approach introduced by economic geographers to the study of innovation networks and used in industrial clusters, regional innovation systems and agglomeration economy, knowledge spillover, etc., and has shown good applicability. In view of this, this paper applies social network The network analysis method, using Ucinet and Gephi software, is based on the overall network topology and individual network topology The structure studies the characteristics and development evolution process of the technological innovation network of China's logistics industry. Combined with the research objectives of this paper The following indicators were selected to measure the innovation network.

①Network size

The network size can be expressed in terms of the number of nodes within the network, which reflects the participation of innovation agents in the network.

The large scale of the network indicates that the number of network subjects is large, and each subject can access resources on a larger scale and is more likely to Ability to make technological innovations.

②Network Density

Network density reflects how well connected the network

is as a whole. A high-density innovation network can provide innovation capital The source propagation provides a more efficient and stable environment. It is calculated by the formula .

$$D = \frac{l}{n(n-1)/2}$$

where l denotes the total number of edges contained in the network and n represents the total number of network nodes.

③ Clustering factor

Clustering coefficient is the degree of clumping of nodes in the network. A higher agglomeration coefficient indicates that the phenomenon of network factional cooperation

The more prominent, the higher the cohesiveness of the network. The average clustering coefficient is calculated by the following formula:

$$C = \frac{1}{n}\sum_{i=1}^{n}\frac{e_i}{k_i(k_i-1)}$$

where: n denotes the number of nodes, ande_i denotes the number of edges between node i and its own neighbors;k_i denotes the number of edges between the number of neighboring points of i; $k_i(k_i-1)$ denotes the maximum number of possible edges that exist.

④Network center potential

The network centrality potential is used to describe the centrality of the network, which mainly measures the degree of equilibrium or deviation of the network as a whole.

degree. Its calculation formula is .

$$C = \frac{\sum_{i=1}^{n}(C_{max}-C_i)}{\max[\sum_{i=1}^{n}(C_{max}-C_i)]}$$

In the formula, theC_{max} denotes the network node with the highest centrality, andC_i The larger the value of C, the higher the central potential of the network.

⑤Small-worldness

Small-worldness reflects the connectivity of the nodes in the network and, to some extent, the degree of network accessibility.

The method of determining the small world quotient is given here and is calculated as follows:

$$Q = \frac{C/C_r}{L/L_r}$$

where C denotes the agglomeration coefficient of a random network of equal size of the innovation network, L denotes the innovation network The average path length of a random network of the same size. If the small-world quotient is much larger than 1, the more the network conforms to the "small-world" property.

3. Network Characterization

3.1. Overall situation analysis

Through the simple statistics of the logistics industry patent data, it can be found that the innovation achievements of the logistics industry have been increasing with the passage of time. According to the law of development of logistics industry, combined with the changes of patent transfer data of logistics industry, the development of technological innovation in China's logistics industry can be divided into three stages:

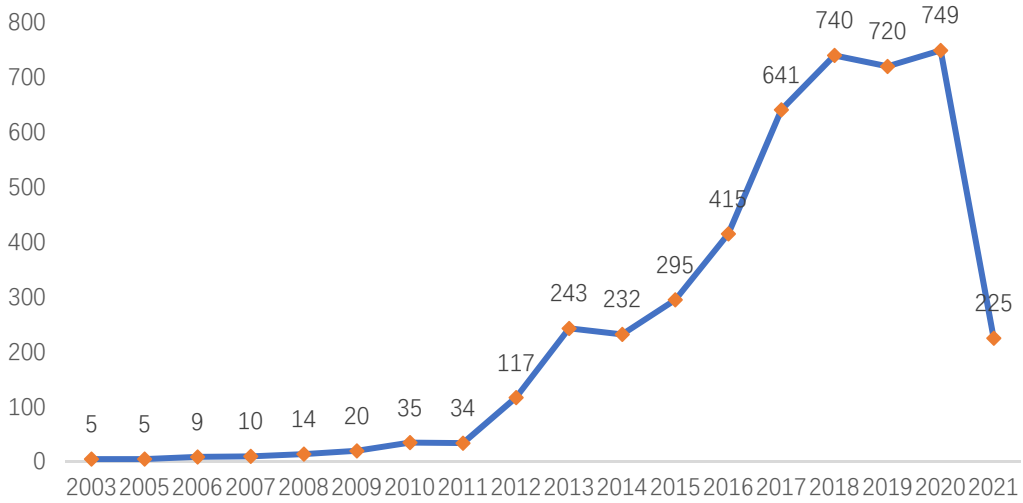
The first stage is 2003-2011, along with the establishment of Taobao in 2003, e-commerce has become an important way to promote consumer and logistics circulation, the rise of e-commerce network economy makes people turn to focus on the bottleneck of "logistics". At the same time, this phase of the logistics industry by the national government at all levels, the state to strengthen the development of the logistics industry planning, logistics policy environment has been significantly improved, China's modern logistics industry into a rapid development track. 2000, China's "Tenth Five-Year" logistics development goals formally established; 2001, the former State Economic and Trade Commission and other In 2001, the former State Economic and Trade Commission and other six ministries and commissions issued "a number of opinions on accelerating the development of modern logistics in China"; in 2004, the National Development and Reform Commission and other nine ministries and commissions issued "opinions on promoting the development of modern logistics industry in China". Various places have also issued relevant regulations and policy measures to plan and build logistics parks, logistics centers and distribution centers, effectively promoting the integration and consolidation of various logistics functions and elements. Under the vigorous promotion of national and local governments, relevant enterprises actively participate in the transformation or innovative development of logistics business in the modern sense, a large number of logistics warehousing, transportation and distribution enterprises develop and grow, logistics supply capacity is significantly enhanced, logistics socialization and specialization is developing at a faster pace, and the concept of logistics is being understood and accepted by more and more enterprises. The scale of China's logistics industry continues to expand, showing a sustainable development trend.

The second stage is 2012-2016, this stage of the logistics industry gradually into the automation stage, combined shelves, AGV was born, fully automatic control system began to be widely used, the Internet information platform, Electronic Data Interchange (EDI), Global Positioning System (Global Positioning System (GPS) radio frequency identification (Radio Frequency identification, RFID) and bar codes and other modern information technology means in logistics management and logistics technology is widely used, so that logistics modernization has reached a new level. In 2012, the Ministry of Commerce issued the "Guidance on Promoting the Transformation and Upgrading of the Warehousing Industry" to guide the transformation of warehousing enterprises from traditional warehousing centers to multi-functional and integrated integrated logistics service providers; in 2016, the General Office of the State Council forwarded the National Development and Reform Commission's "Logistics Industry Special Action Plan for Cost Reduction and Efficiency Improvement (2016-2018)". This period of rapid development of the logistics industry, but also more focused on solving the circulation of goods in the process of transportation, warehousing, packaging, handling, distribution processing, distribution and other related aspects of cost reduction and efficiency, technological innovation to improve circulation efficiency, China has initially formed a new pattern of technology-driven logistics development.

The third stage is 2017-present, along with the rise of a new generation of information technology such as the Internet of Things, cloud computing, big data, artificial intelligence, etc. In 2017, the State Council issued the "New Generation of Artificial Intelligence Development Plan" (Guo Fa [2017] No. 35), emphasizing the vigorous development of intelligent

logistics, artificial intelligence to help intelligent logistics. The application of various international leading technologies such as unmanned warehouse, unmanned vehicle, unmanned aerial vehicle (UAV), logistics robot, cloud warehouse, etc., are all technology driven by big data and artificial intelligence. Future logistics demand growth is slow, manpower begins to gradually liberate, the growth trend to ecological development, logistics development towards high quality, strong technology and other standards of steady development. Emphasis is placed on the coordinated development of multiple fields, and new technologies such as the Internet of Things and blockchain are laid out to visualize the entire logistics chain. This period of logistics development from quantitative to qualitative development, in a new phase of rapid technological innovation and technological transformation.

From the viewpoint of patent transfer data, there is a lack of innovative technology flow within the industry in the early stage, but with the development of logistics industry, the rapid rise of e-commerce, and the continuous changes of emerging technologies, the technological innovation flow of logistics industry is gradually frequent. the number of technological innovation transfer is within 100 times between 2003 and 2011, and the number of patent transfer has increased significantly since 2012, from 117 times in 2012 to The number of patent assignments per year from 2017 has increased to more than 700, and the mutual flow relationship between the various subjects of the technological innovation network of China's logistics industry has become closer and closer.



3.2. Network subject analysis

Individual characteristics of specific nodes in the network are analyzed, and the centrality and structural hole index of each point are calculated to reflect the position of the nodes in the network.

Ltd., China International Shipping Container (Group) Co., Ltd. and Institute of Engineering Thermophysics of Chinese Academy of Sciences have relatively high out-do center degree, i.e. the subjects have higher degree of transferring technological innovation results related to logistics. Ltd., Shenzhen CIMC Intelligent Technology Co., Ltd. and Hengyang Zhongke Zhongneng Green Nursery Technology Co., Ltd. have relatively high degree of in-degree centrality, which means that the relevant innovation subjects pay more attention to the knowledge learning for technological innovation achievements. The subjects with higher degree centrality have a higher degree of connection with other innovation subjects in the network, which indicates that they have a greater influence in the network and are in the core position. On the whole, the germination stage of the network and the awareness of technology innovation transmission are poor, and the innovation subjects with higher ranking are mostly science and technology enterprises and research institutes, while large logistics enterprises participate in the network but small and medium-sized logistics enterprises rarely join the network, and most of them have a small number of patents. Technological innovation has just started, and the real core nodes have not yet appeared.

2012-2016 network formation stage. at this time, the continuous change of information technology, the rapid development of Internet technology, led to the vigorous development of logistics information technology, warehouse management system (WMS), transportation management system (TMS), bar code technology, GPS and RFID technology and other logistics information technology has been used to promote the rapid development of domestic logistics development. With the significant expansion of network scale, the frequency of technology flow within the network increases, the number of points with large degree centrality increases, and the types of innovation subjects in core nodes also change. In terms of centrality, Tianjin Yingde Technology Co., Ltd, Beijing Jingbangda Trading Co., Ltd, Jiangnan University, Tianjin Yingde Cold Chain Technology Co., Ltd, Beijing Jingdong Zhenshi Information Technology Co., Ltd and Beijing Deep Awake Intelligent Technology Co., Ltd become the innovation subjects with the highest degree centrality of network outgoing and incoming degrees in this period, occupying the main core position in the network and having strong control over the overall resources in the network. The structure hole data shows that Beijing Jingdong Zhenshi Information Technology Co., Ltd, Beijing Jingbangda Trading Co., Ltd and Nanjing Sanbao Technology Co., Ltd are located in the "bridge" position of the network, which is conducive to the nodes to obtain more resources for exploratory innovation. Compared with the budding stage of China's logistics industry technology innovation network, logistics enterprises gradually highlight their core subject position in this stage, and the core position is gradually transferred from the main body of enterprise logistics to the

main body of logistics enterprises, while universities and research institutes still occupy part of the main position in the network, in general, this stage has initially built up a logistics Industrial technology innovation network has taken shape.

2017-2021 network development phase. 2016, the General Office of the State Council forwarded the National Development and Reform Commission "Logistics cost reduction and efficiency special action plan (2016-2018)". February 2019, the National Development and Reform Commission and other departments jointly issued "on promoting high-quality development of logistics to promote the formation of a strong domestic market Opinions" introduced to build a high-quality logistics infrastructure network system and other measures to consolidate the results of logistics cost reduction and efficiency gains, enhance the vitality of logistics enterprises, and improve the level of efficiency and effectiveness of the industry smooth the operation of the entire logistics chain. In recent years, policies across the country frequently mentioned to encourage the development of intelligent logistics. The development of intelligent logistics has become one of the effective ways to help the logistics industry to achieve cost reduction and efficiency. 2019 government work report clearly pointed out: to promote the wide application of big data, cloud computing, Internet of things in various fields. At the same time, the National Development and Reform Commission issued the "Internet +" efficient logistics implementation opinions" and the Ministry of Transport and other 11 departments jointly issued the "guidance on promoting the quality of logistics services to improve the work" proposed to "innovative logistics service model", encourage Enterprises actively use the Internet and other modern information technology to transform business processes, strengthen the use of big data mining, improve service efficiency, and improve customer experience. In this period, the logistics industry aims at high-quality development and enters an important stage of quality development driven by innovation. The technology flow generated by the logistics industry technology innovation network around the core nodes in this stage continues to grow rapidly, and Jingdong Group, as an integrated enterprise of e-commerce and supply chain services, occupies the core position of China's logistics industry technology innovation network and becomes a continuous innovation node. At this stage, the important position of the core subject is highlighted, while other logistics enterprises gradually grow into important nodes of the network, and enterprises focusing on intelligent logistics tools, such as New Stone Dragon Code (Beijing) Technology Co. The increase of the nodes promotes the innovation subject to obtain more technical resources, which is conducive to the transmission of logistics technology.

In summary, in China's logistics industry technology innovation network, gradually from the budding enterprise logistics-oriented innovation main body to the core logistics enterprises as the main position, other logistics enterprises as important nodes of the innovation network, universities and research institutes in the overall network development of the power gradually weakened.

Table 1. Ranking of the center degree of technological innovation main body of logistics industry in China at different stages

Stage	Name	Out degree center degree	Relative out degree center degree	Name	Incidence center degree	Relative Incidence Center Degree
2003 - 2011	Anhui Julong Drive Technology Co.	14	0.102	Ningguo Julong Speed Reducer Co.	14	0.102
	China International Shipping Container (Group) Co.	10	0.073	Shenzhen CIMC Intelligent Technology Co.	10	0.073
	Institute of Engineering Thermophysics, Chinese Academy of Sciences	7	0.051	Hengyang Zhongke Zhongneng Green Garden Technology Co.	6	0.044
	Beijing Sanbo Zhongzi Technology Co.	4	0.029	CGN Intelligent Technology (Shenzhen) Co.	4	0.029
	Yueyang Changde Chemical Industry Co.	4	0.029	Wu Zhaoxiang	4	0.029
	Changzhou Simanray Information Technology Co.	4	0.029	Yueyang Changde Environmental Technology Co.	4	0.029
	Li Yuanzhao	4	0.029	Hangzhou Hongqi Information Technology Co.	4	0.029
	Shenzhen Tianqin Supply Chain Service Co.	4	0.029	Shenzhen Qianhai VWY International Trade Co.	4	0.029
	China National Offshore Oil Group Co.	3	0.022	China National Offshore Oil Corporation	3	0.022
	Beijing Low Carbon Clean Energy Institute	3	0.022	Sinopec Shanghai Engineering Co.	3	0.022
2012 - 2016	Tianjin Yingde Technology Co.	39	0.039	Tianjin Yingde Cold Chain Technology Co.	39	0.039
	Beijing Jingbangda Trading Co.	30	0.030	Beijing Jingdong Zhenshi Information Technology Co.	29	0.029
	Jiangnan University	26	0.026	Beijing Deep Awake Intelligent Technology Co.	18	0.018
	Liaoning Julong Haimuxing Intelligent Logistics Technology Co.	26	0.026	Jurong (Shanghai) Enterprise Development Co.	18	0.018
	Beijing University of Aeronautics and Astronautics	18	0.018	Kunming Kunshan Logistics Information Industry Co.	15	0.015
	Sichuan Youhuo Technology Co.	18	0.018	China National Petroleum Corporation	14	0.014
	Yunnan Kunshan Design and Research Institute Co.	17	0.017	Beijing North Huachuang Microelectronics Equipment Co.	14	0.014
	Huzhou Zhanye Logistics	16	0.016	Jiangsu Zhiyun Technology	14	0.014

	Machinery & Equipment Co.			Development Co.		
	China Packaging Research and Testing Center	14	0.014	Wuhu Ande Smartlink Technology Co.	14	0.014
	Northern Huachuang Technology Group Co.	14	0.014	Liuzhou Shentong Auto Technology Co.	12	0.012
2017 - 2021	Beijing Jingbangda Trading Co.	212	0.076	Beijing Jingdong Qianshi Technology Co.	214	0.077
	Tianjin Jingdong Shentuo Robotics Technology Co.	62	0.022	Beijing Jingdong Zhenshi Information Technology Co.	62	0.022
	xiamen cha re-injection packaging co.	22	0.008	Shanghai Shenxue Supply Chain Management Co.	56	0.020
	Zhejiang Shen Zhen Machinery Technology Co.	20	0.007	Shanghai Yufeng Youdao Intelligent Technology Co.	18	0.006
	Nanjing Hanxi Yue Automation Technology Co.	19	0.007	Liu Guoqiang	12	0.004
	Huzhou Huihe Machinery Equipment Co.	18	0.006	Anhui Xingmeng Supply Chain Management Co.	12	0.004
	Qian Wenjuan	16	0.006	Baokai (Shanghai) Intelligent Logistics Technology Co.	10	0.004
	Shenzhen Chunhui International Freight Forwarding Co.	15	0.005	Huzhou Huineng Electromechanical Technology Co.	10	0.004
	Suzhou Jinming Transportation Co.	14	0.005	Qianli (Shanghai) Intelligent System Equipment Co.	10	0.004
	Chen Hanyuan	14	0.005	Liu Zhimin	9	0.003

Table 2. Different stages of China's logistics industry technology innovation network structure hole location ranking

Stage	Innovation subject	Structural hole limit system
2003-2011	China National Offshore Oil Corporation	0.625
	Institute of Engineering Thermophysics, Chinese Academy of Sciences	0.755
2012-2016	Beijing Jingdong Zhenshi Information Technology Co.	0.933
	Beijing Jingbangda Trading Co.	0.876
	Nanjing Sanbao Technology Co.	0.876
	Yunnan Kunshan Design and Research Institute Co.	0.785
	Anqing Blue Coral Ecological Agriculture Technology Co.	0.680
	Beijing Jingdong Qianshi Technology Co.	0.625
	China Packaging Research and Testing Center	0.592
	Wuhu Ande Smartlink Technology Co.	0.592
	Shunfeng Express Co.	0.592
	Liaoning Julong Haimuxing Intelligent Logistics Technology Co.	0.574
2017-2021	Neolithic Dragon Code (Beijing) Technology Co.	0.820
	Zhejiang Shen Zhen Machinery Technology Co.	0.820
	Wenzhou Jet Technology Co.	0.755
	China AgriLink Holdings Limited	0.680
	Anhui Wentian Information Technology Co.	0.680
	Anhui University of Technology	0.680
	Shandong Shiku Intelligent Technology Co.	0.680
	Hebei Zhongyan Technology Service Co.	0.680
	Shenzhen Jiufangtongxun E-Commerce Logistics Co.	0.680
	Chongqing Henghou E-Commerce Co.	0.680

3.3. Overall network characteristics analysis

(1) The overall scale of the network continues to expand showing the characteristics of "small concentration and large dispersion".

In terms of network scale, the number of nodes in the network increased from 2003 to 2021, and the network scale grew from 138 nodes in 2003 to 2779 nodes in 2021, an increase of 20.14 times. The scale of the innovation network in China's logistics industry gradually expanded during 2003-2021, and the flow of technical knowledge between various nodes became more frequent. In terms of network density, overall, the network density decreases from 0.0034 to 0.0002. From each stage, the number of nodes in the first stage of the network is relatively small at 138, and the network as a whole appears to be dense due to the limited main body, while the influx of a large number of new nodes in the second and third stages forms many isolated scattered points, resulting in the overall network density decreasing to 0.0002. In terms of the evolutionary characteristics of the overall scale and density of the innovation network, the evolution of the technological innovation network in China's logistics industry is in an active development stage. The frequency of new themes in the innovation network is more frequent, and more new flow relationships are generated, and the scale of the innovation network is expanding, while the network density shows a decreasing trend, with the characteristics of "small agglomeration, large dispersion".

(2) The central potential of the network shows U-shaped characteristics, and the core subject gradually increases

In terms of network central potential, the network central potential in the evolution of China's logistics industry

technology innovation network shows U-shaped characteristics, manifested in a larger network central potential in the first phase period 2003-2011, a decrease in the second phase network central potential, and a further rise in the third phase 2017-2021. The network central potential can reflect the overall equilibrium state of the network, the larger the value of this indicator the stronger the control of the central node of the network, the more the overall deviation from the equilibrium state. 2003-2011 period, the out degree central potential is 9.542%, the in degree central potential is 9.542%, because at this time the flow of technological innovation in China's logistics industry is less, the core node's ability to control resources is more prominent. 2012- The central potential of the innovation network during 2016 is 3.825%, during the period of rapid development of technological innovation in logistics industry, the rapid expansion of the network scale leads to the increase of the number of core subjects, and the logistics industry, as an innovation-loose industry that is different from the innovation-intensive industries such as electronic information industry, has a looser network resource allocation. the out-degree of the technological innovation network in logistics industry during 2017-2021 The central potential is 7.593% and the entry degree central potential is 7.665%, on the basis of further expansion of the network scale, the increase of the network central potential highlights that the innovation network center gradually begins to appear in the new period driven by digital technology, and the configuration of network resources is partially clustered at this time. Overall, the technological innovation network of China's logistics industry has gradually started to loosely expand to multi-core subjects after experiencing the development of technological innovation from the small-scale agglomeration period, and the innovation network has gradually become closely connected and the core subject status of the network center has started to emerge under the high-speed development of digital technology and the foundation support of modern logistics industry.

(3) The network connectivity has an inverted U-shaped trend, with better accessibility but less obvious small-world characteristics.

The average shortest path of the network in the three stages shows a trend of first increasing and then decreasing, and the average shortest path reflects the connectivity of the network, which shows that there are fewer network subjects in the small-scale network of logistics industry technology innovation in the first stage, when the network connectivity is higher and the intensity of technology flow is large. In the second stage of rapid expansion of the network scale, the average shortest path grows from 1.0154 to 1.0199, and at this time the network connectivity is slightly less than the previous stage, due to the rapid expansion of the network in the period of rapid development, which leads to the logistics industry technological innovation network focusing more on the mutual flow between innovation subjects. In the third stage of further network development, the shortest path of innovation network decreases from 1.0199 to 1.0160, which shows that the expansion of network scale in this stage is accompanied by the gradual formation of mutual flow of innovation network. The average path length of the network stays around 1.1, which indicates that the nodes within the network need about 1.1 intermediaries on average to produce connections. The short average path length indicates that the network has high accessibility within the network, which is conducive to the nodes' rapid access to technology. However, in terms of network small-worldness, the small-world characteristics of China's logistics industry technology innovation network are not obvious. Small-world network theory points out that the key nodes in the network world are mostly innovation subjects with high degree of centrality, and the number of innovation links between innovation subjects also depends mainly on the collaboration between these innovation subjects. Small-worldness is mainly judged by two indicators: average path length and agglomeration coefficient. When the clustering coefficient of the network is larger than the average clustering coefficient of random network nodes of the same size and the average path length is shorter, this network is called a small-world network. In the technological innovation network of China's logistics industry, the average shortest path shows an inverted U-shaped trend in the development stage and the network clustering coefficient is 0. It can be seen that in the innovation network with innovation subjects as nodes, the logistics industry innovation subjects are mainly connected with each other by two, and the overall network structure does not have a closed triangle network, so it does not yet have the characteristics of a small world network.

Table 3. Integral network indicators of logistics industry technology innovation network

Stage	Number of nodes	Overall network density	Average degree	Average shortest path	Out of the degree of central potential	Into the degree of central potential
2003-2011	138	0.0034	0.4638	1.0154	9.542%	9.542%
2012-2016	989	0.0005	0.4985	1.0199	3.825%	3.825%
2017-2021	2779	0.0002	0.5977	1.0160	7.593%	7.665%

4. Cyberspace Evolution Analysis

From 2003 to 2021, China's logistics industry technology innovation network has been stretched in urban spatial scale, and the innovation cooperation has continued to be deepened and densely developed. The technology flow of logistics industry technology innovation between cities has mostly covered cities above prefecture level in China, and the scale of the network has increased from 43 city nodes to 114, which has greatly extended the scope of access to innovation resources. The innovation linkages within the city scale are frequent, the intensity of technology flow continues to deepen, and the average degree of the network increases dramatically at the same time. Network density data, on the other hand, show that the overall logistics industry technology innovation network in China shows an upward trend, with closely interconnected city nodes and an obvious trend of network densification. Among them, the number of urban innovation network nodes and the number of connections rose rapidly from 2012 to 2016 due to the rapid development stage of

logistics industry technology innovation, but the newly incorporated network nodes have not yet formed extensive connections with established cities, and the network density decreased slightly in comparison.

In degree centrality between 2003 and 2021, core cities are more stable and increase over time.Core city membership has increased. The highest value of city degree centrality in the first stage is 10, and in the second and third stages of rapid expansion of the innovation network, the lowest degree centrality among the top ten cities in the degree centrality ranking is 13 and 28, respectively, and the cities with dominant positions in the network are increasing. However, with the expansion of the network, cities with low degree centrality account for the majority, reflecting that the innovation of logistics industry tends to form a core-edge pattern geographically. From the first stage to the second stage, the spatial layout has obvious migration characteristics from north to south, and the spatial layout from the second stage to the third stage shows a strengthening trend of the center of gravity toward the east. Specifically, Beijing and Shanghai, as municipalities directly under the central government, have an important and stable position in the economic and technological innovation network of the logistics industry, showing certain control and leadership over the innovation network. Other cities with strong performance include Shenzhen, Guangzhou, Hangzhou, Suzhou and Nanjing, etc. In general, first-tier and super first-tier cities have more central positions in the technological innovation network of China's logistics industry.

Table 4. Different stages of China's logistics industry technology innovation city center degree ranking

Out degree degree center degree		Into the degree degree center degree	
Beijing	10	Beijing	5
Shanghai	5	Shenzhen	4
Hefei	4	Xuancheng City	4
Shenzhen	3	Hangzhou	3
Suzhou	3	Nanjing	3
Luoyang City	2	Hefei	2
Shaoxing	2	Nantong	2
Hangzhou	2	Dalian	2
Changzhou	2	Changshu	2
Anshan City	2	Changsha	2
Wuxi	46	Beijing	50
Hangzhou	25	Shanghai	49
Shanghai	24	Shenzhen	23
Beijing	21	Taizhou City	23
Chengdu	20	Nanjing	21
Shenzhen	20	Jiaxing City	18
Nanjing	17	Suzhou	15
Guangzhou City	17	Guangzhou City	14
Tianjin	16	Nantong	14
Huzhou City	16	Huzhou City	13
Hangzhou	86	Shanghai	125
Guangzhou City	70	Shenzhen	87
Shenzhen	55	Suzhou	80
Suzhou	53	Beijing	65
Beijing	51	Guangzhou City	54
Nanjing	46	Wuhan	36
Quanzhou	42	Tianjin	33
Shaoxing	37	Nanjing	32
Tianjin	35	Nantong	31
Hefei	34	Foshan City	28

2003-2011 China's logistics industry technology innovation budding stage, the formation of Beijing as the main core node, Shanghai, Hangzhou, Nanjing as an important node of the spatial pattern, this stage involves the scope of North China, Northeast China, East China, Central China, but mainly for the internal flow of technology between regions and more, the core node of the control and leadership of the network is prominent, the role of bridge city nodes slightly not enough.

During the rapid development phase of the network from 2012 to 2016, the innovation network expanded rapidly at the city scale, and some fast-developing cities began to play a radiating role in the surrounding areas, and the coverage area of the logistics industry technology flow extended to the northwest and southwest regions. Basically, a "double-core-multi-center" city pattern of China's logistics industry technology innovation network has been formed, that is, Beijing and Shanghai, as the political and economic center cities in China, have the absolute core position in the network, and the provincial capitals and first-tier cities of each region as the central body radiates to other cities in the technology flow. The capacity of the network is gradually emerging.

From 2017 to 2021, the inter-city flow of China's logistics industry technology innovation network further develops and basically stabilizes, and the scope of technology flow basically covers all provinces in China, among which North

China and East China still occupy an important position in the innovation network, and the city-scale innovation network "double core - multi-center" pattern continues to be solid. Due to the expansion of the network scale, the network trend of "small agglomeration - large diffusion" is presented at this time, i.e., in the small agglomeration network with Beijing and Shanghai as the core cities, supplemented by Shenzhen, Nanjing, Suzhou, Chengdu and other bridge cities, the technology exchange among cities is closer. At this time, most cities in the northwest and northeast regions show the characteristics of low breadth and weak depth, and are in a disadvantageous position in the network.

5. Research Findings and Insights

This study takes the technological innovation activities of China's logistics industry as the research object, constructs the network matrix using the data of patent transfer of logistics industry technological innovation, and analyzes the characteristics of China's logistics industry technological innovation network and the network evolution on the spatial scale using the social network analysis method, and the main conclusions are as follows: (1) China's logistics industry technological innovation network has experienced three stages: 2003-2011, 2012- 2016, and 2017 to the present, the logistics industry technological innovation network presents an overall development, and the logistics industry technological innovation has realized a new development pattern from quantitative to qualitative transformation. (2) The core subjects of the technological innovation network of China's logistics industry gradually appear, from the prototype of the technological innovation network of logistics industry with enterprise logistics as the core and universities and research institutes as the main subjects during the network formation period, to the network form with integrated logistics enterprises as the core subjects of innovation gradually. (3) The evolution of technological innovation network of China's logistics industry is in an active development stage. The frequency of new subjects in the innovation network increases more frequently, generating more new flow relationships, and the scale of the innovation network is expanding, while the network density shows a decreasing trend, with the characteristics of "small agglomeration, large dispersion". (4) In the spatial scale of the city, the development trend is dense, and the spatial layout has obvious characteristics of migration from north to south, showing the trend of strengthening the center of gravity toward the east.

Based on the above findings, the following recommendations are made to promote the rapid and stable development of technological innovation networks in China's logistics industry:

(1) Around the core body of the logistics industry, establish and improve the logistics industry science and technology innovation network. Establish a logistics technology research and development system that combines industry, academia, research and application, play the leading role of large logistics enterprises, supply chain core enterprises, strengthen the deep integration of industry, academia and research, and create a specialized innovation platform for the logistics industry. Build a logistics technology research and development platform, relying on industry-advantaged enterprises and scientific research institutions, integrate scientific research resources, jointly carry out major key technology research and development and industrialization application demonstration, and cultivate scientific and technological innovation main body. Strengthen the deep integration of industry, academia and research, encourage all kinds of universities, research institutes, large enterprises with the actual needs, jointly establish R & D centers or innovation centers and other innovation carriers, to create a number of "double first-class" logistics disciplines professional universities. Accelerate the promotion of industry-university-research cooperation, relying on the China Logistics Association and the Logistics Industry Association to build a number of industry-oriented science and technology innovation service platform, the organization to carry out for different fields, different levels of international exchanges and cooperation.

(2) Give full play to the role of resource endowment of core cities and promote cross-regional flow of logistics innovation resources. Give full play to the radiation-driven role of core cities to drive the coordinated development of neighboring cities. In the eastern region, make full use of the role of national logistics hub bearing cities given at the national level, promote the construction of key cities in the eastern region into modern logistics clusters, and accelerate the construction of railroad international logistics corridors and other transportation facilities. Promote the accelerated development of the central and western regions, and promote industrial and economic transformation and upgrading. In the western region, the construction of logistics parks as a carrier and reliance, and actively attract all kinds of enterprises to the park agglomeration, improve the market environment, infrastructure, public services and other supporting facilities, encourage enterprises to participate in the construction and operation of the park through a variety of ways to promote the agglomeration and use of resources, and promote the transformation and upgrading of industries in the region. In key cities in the eastern region to build international port city and other functional areas and carriers to attract the world's top 500, multinational headquarters or regional headquarters to station.

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