A Social Network Analysis of Generic Technological Innovation Cooperation in China's Electronic Information Manufacturing Industry——Based on the Perspective of Industry Chain

Qi Wang
1511841407@qq.com

Harbin Engineering University

Abstract. Taking the patent data of generic technical cooperation in China's electronic information manufacturing industry from 2011 to 2020 as a research sample, this paper constructs generic technological innovation cooperation networks based on the industry chain, and divides it into three periods: 2011-2014, 2015-2017 and 2018-2020, we calculate network characteristics by using Ucinet6.0 software, and uses social network analysis method to analyze them. The results show that the network density of the innovation cooperation is low, and most of the innovation subjects tend to cooperate around fixed partners, gaps in innovation subjects make it difficult to further share information.

Keywords: Social Network Analysis; Industry Chain; Innovation Cooperation; Generic Technology

1 Introduction

In the context of "Industry 4.0", global technology competition has gradually developed from monomer technology competition to generic technology competition [1]. In response, China has successively issued "Made in China 2025" and "Industrial Key Technology Development Guide 2017", pointing out the important role of industrial generic technological innovation in China's economic growth. Generic technology with the characteristics of large R&D investment, high difficulty, high risk and strong externality [2], leads to innovation subjects have complex connections in the process of cooperation, thus forming a generic technology innovation cooperation network. In the research on technological innovation cooperation networks, scholars mainly analyze network characteristics and their evolution from two aspects: network structure characteristics and network subject characteristics [3, 4, 5, 6], and insufficient research on the characteristics of generic technological innovation cooperation networks. Therefore, taking China's generic technical cooperation patent data as a research sample, this paper uses Ucinet6.0 software to construct generic technological innovation cooperation networks of the whole industry chain, the up-midstream and mid-downstream links based on the industry chain, and the social network analysis method is used to explore the internal structure and important nodes of the network, expands the research on generic technological innovation cooperation, and provides reference for government policy formulation and the direction of cooperative R&D of innovation subjects.

MSIEID 2022, December 09-11, Chongqing, People's Republic of China

DOI 10.4108/eai.9-12-2022.2327611

2 Methods and materials

2.1 Data source and processing

As an important component of China's strategic emerging industrial sector, electronic information manufacturing industry is a key breakthrough area for improving the competitiveness of China's industry chain and value chain. Therefore, this paper takes the patent data of generic technical cooperation in China's electronic information manufacturing industry from 2011 to 2020 as a sample, and divides the electronic information manufacturing industry chain into three links: upstream parts links, midstream component links and downstream overall products[7], and analyzes the characteristics of generic technological innovation cooperation network based on the industry chain.

The data collation process in this paper is as follows: (1) We search for electronic information manufacturing patents in PatSnap global patent database, and download a total of 71443 electronic information manufacturing patent data from 2011 to 2020. (2) This paper draws on technology co-occurrence rate analysis method based on Luan Chunjuan, judges the technology co-occurrence rate is greater than 20% as the industrial generic technology[8], and screens out generic technology patent data of electronic information manufacturing industry, whose first three numbers of IPC main classification are G06, H01, H04 and H05. (3) We extract patent data of patent applicant ≥ 2, and reject patent data of individual, non-Chinese and non-standard, finally obtain 3545 generic technological innovation cooperation data. (4) We judge which industry chain the 3545 patents belong to one by one, and there are 116 in the upstream, 2625 in the midstream, and 804 in the downstream. (5) This article makes a preliminary judgment on the patent data of common technology cooperation and the development stage of our electronic information manufacturing industry, divides the generic technology innovation cooperation of the electronic information manufacturing industry into three periods: 2011-2014, 2015-2017 and 2018-2020.

2.2 Methods

Taking the electronic information manufacturing industry as an example, taking the innovation subject as the network node and the cooperation as the edge of the network, this paper uses Ucinet6.0 software to calculate the network characteristics of the whole industry chain, and up-midstream and mid-downstream. Referring to the practice of most scholars [9], this paper uses the social network analysis method to analyze the generic technological innovation cooperation network characteristics in China’s electronic information manufacturing industry from the network structure and network subject.

The indicators of network structure characteristics are as follows: (1) Network size. It’s represented as the number of network nodes. The greater the number of nodes, the greater the possibility of network innovation subject to obtain information and resources. (2) Network density. It’s expressed as the ratio of the actual number of cooperation between network nodes to the theoretical maximum number of cooperation, reflecting the closeness of the cooperation of innovation subjects within the network and the impact on the behavior of innovation subjects. If there are n nodes in the network, the maximum possible theoretical value of the total number of relationships contained therein is $n(n-1)/2$. If the actual number of relationships contained in the network is m, the calculation formula of the network density π is:

$$\pi = m/n(n-1)/2 = 2m/n(n-1) \quad (1)$$

(3) Average distance. It's used to represent the average length of the distance between any two nodes in the network. The smaller the average distance, the more convenient the information transfer between the network innovation subjects. If there are n nodes in the network, l_{ij} represents the distance between nodes i and j, then the formula for calculating the average distance L between network nodes is:

$$L = \sum_{i \neq j} l_{ij}/n(n-1) \quad (2)$$

(4) Cohesion index. It indicates the minimum number of independent paths between nodes. The larger the index, the more equal the innovation subjects in the network, and the more stable and uniform the network structure. (5) Clustering coefficient. It refers to the probability that two nodes directly connected to a given node are also directly connected to each other, which is used to measure the degree of network node tendency to cluster. If there are n nodes in the network, C_i represents the clustering coefficient of node i, and C_i is the individual network density of node i, then the clustering coefficient C of the network is the average of the density coefficients of each node, and the calculation formula is:

$$C = C_i/n \quad (3)$$

The indicators of network subject characteristics are as follows: (1) Degree centrality. It's a measure of the direct relationship between network nodes, which is used to describe the importance of innovative agents in the network. The greater the degree centrality, the more nodes directly connected to the node, and the node is at the core of the network. (2) Betweenness centrality. It refers to the degree to which the network node is located in the "middle" of the other two nodes in the network, which depicts the degree to which the network innovation subject controls the resources. The greater the betweenness centrality, the more likely it is to control the connection between other nodes. (3) Closeness centrality. It refers to the distance between a node in the network and all other nodes in the network, which is used to indicate the extent to which the network innovation subject is not controlled by other subjects. The greater the closeness centrality, the easier it is for the node to transmit information and the less easily it is controlled by other nodes. This paper uses relative values to represent the three centrality of network nodes so as to facilitate comparison of data. Further, referring to Wu Feifei's practice, we establish the x, y, z coordinate axes with three centrality as the three-dimensional coordinate system, and the area formed with the Euclidean distance from the node coordinate to the origin as the radius represents the node influence [10]. Then the Euclidean distance from node i (x, y, z) to the origin is calculated as follows:

$$|X| = \sqrt{x^2 + y^2 + z^2} \quad (4)$$

3 Analysis and discussion

3.1 Analysis of network structure characteristics

This paper uses the visualization tool Netdraw of Ucinet6.0 software to draw the network maps of 2011-2014, 2015-2017 and 2018-2020, as shown in Figure 1. And we calculate the structure indicators of three generic technological innovation cooperation network in the electronic information manufacturing industry in three periods by using Ucinet6.0 software, and the results are shown in Table 1. Combined with Figure 1, the analysis is as follows:

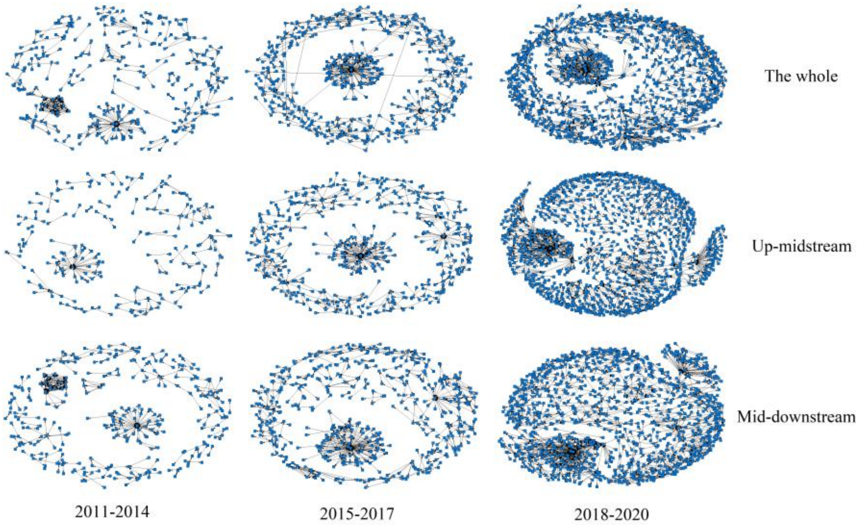

Fig. 1. Generic technology innovation cooperation network maps

(1) Network size and network density. The three networks have the same trend of change in size and density, the network size is increasing, but the network density is gradually decreasing, indicating that the number of innovative subjects participating in cooperation is increasing, but the cooperative relationship has not yet been established, and most of the innovative subjects are more inclined to establish cooperative relations with familiar partners around, showing the characteristics of strong relationship network. (2) Average distance and cohesion index. With the change of time, the average distance of the whole network and the mid-downstream network increases, and the cohesion index first increases and then decreases, indicating that because there was no obvious difference between the network innovation subjects in the early stage, it is more inclined to actively seek more partners to establish a cooperative and shared relationship, and the influence of some subjects continues is increasing, then the development differences among innovation subjects make it difficult to share more general technical information, the transmission of important information becomes more difficult. For the up-midstream network, the average distance is increasing, and the cohesion index is decreasing, indicating that it is difficult to establish a deeper cooperative relationship between the innovation subjects, the sharing of generic technical information is becoming more and more difficult, the resources and information are gradually concentrated, and the differences between the innovation subjects are gradually increasing. (3) Clustering coefficient. The Clustering coefficient of the three networks first increased with time and then decreased slightly, indicating that the innovation subjects were more inclined to gather with partners in the early stage and establish cooperative relations, it presented the characteristics of a small world.

To sum up, the generic technology innovation cooperation network of China's electronic information manufacturing industry has the following characteristics: the network size is gradually expanding, yet the network density is gradually decreasing, there is a negative relationship between the two, the network connection is not close enough, and the small-world characteristics is gradually fading.

Table 1. Calculation results of network structure indicators

Indicators	Network Category	2011-2014	2015-2017	2018-2020
Network size	The whole	322	503	1116
	Up-midstream	203	425	1018
	Mid-downstream	305	483	1092
Network density	The whole	0.0066	0.0041	0.0018
	Up-midstream	0.0077	0.0047	0.0020
	Mid-downstream	0.0071	0.0043	0.0019
Average distance	The whole	1.904	2.045	4.43
	Up-midstream	1.856	1.992	4.505
	Mid-downstream	1.905	2.012	4.427
Cohesion index	The whole	0.02	0.024	0.018
	Up-midstream	0.022	0.020	0.018
	Mid-downstream	0.021	0.025	0.018
Clustering coefficient	The whole	0.732	0.765	0.718
	Up-midstream	0.575	0.766	0.711
	Mid-downstream	0.747	0.774	0.725

3.2 Analysis of network subject characteristics

Using Ucinet6.0 software to calculate the degree centrality, betweenness centrality and closeness centrality of all nodes of generic technological innovation cooperation network of the whole industry chain, and up-midstream and mid-downstream in China's electronic information manufacturing industry in 2011-2014, 2015-2017, 2018-2020. And we sort the top 3 network subjects in Euclidean distance as shown in Table 2, Table 3 and Table 4, and analyze them as the main innovation node.

Table 2. Calculation results of network node influence (2011-2014)

Network Category	Network node	Degree centrality	Betweenness centrality	Closeness centrality	Euclidean distance
The whole	SGCC	14.953	2.414	0.369	15.151
	Beijing Huatie Information Technology Co., Ltd	4.984	0.082	0.328	4.995
	China Railway Corporation	4.361	0.031	0.328	4.373
Up-midstream	SGCC	15.842	2.481	0.588	16.046
	Samsung Electronics Co., Ltd	3.96	0.138	0.513	3.995
	China Electric Power Research Institute	3.465	0.038	0.588	3.515
Mid-downstream	SGCC	15.461	2.583	0.392	15.68
	Beijing Huatie Information Technology Co., Ltd	5.263	0.091	0.347	5.275
	China Railway Corporation	4.605	0.035	0.347	4.618

Table 3. Calculation results of network node influence (2015-2017)

Network Category	Network node	Degree centrality	Betweenness centrality	Closeness centrality	Euclidean distance
The whole	SGCC	17.928	3.632	0.247	18.294
	CMCC	4.781	0.219	0.209	4.791
	BOE	1.992	0.036	0.203	2.003
Up-midstream	SGCC	15.094	2.545	0.282	15.31
	CMCC	5.425	0.282	0.249	5.438
	BOE	2.358	0.05	0.241	2.371
Mid-downstream	SGCC	18.465	3.702	0.258	18.834
	CMCC	4.979	0.238	0.218	4.989
	BOE	1.867	0.031	0.211	1.879

As shown in Table 2, Table 3 and Table 4, with the passage of time, the network size continues to grow, and innovation cooperation activities are also on the rise. Among the three networks, the innovation subjects with greater influence are mainly enterprises, among which the State Grid Corporation of China is outstanding, it ranks first in the Euclidean distance and three centrality indexes of the three networks almost all the time, which has relatively strong R&D capital and R&D achievements, SGCC plays an important leading and bridging role in the generic technological innovation cooperation, which has strongly promoted the development of generic technological innovation. In addition, universities and research institutes continue to actively participate in innovation cooperation in all links of the electronic information manufacturing industry chain, and gradually exert influence in the network, such as Beijing University of Posts and Telecommunications.

To sum up, in the cooperative network of generic technology innovation in Chinese electronic information manufacturing industry, enterprises play the main role and have greater control in the network. Universities and research institutes have increased the scope and frequency of cooperation in recent years, and the depth and breadth of cooperation have been improved.

Table 4. Calculation results of network node influence (2018-2020)

Network Category	Network node	Degree centrality	Betweenness centrality	Closeness centrality	Euclidean distance
The whole	SGCC	9.327	3.303	0.118	9.8953
	Beijing University of Posts and Telecommunications	2.511	3.009	0.118	3.9209
	CMCC	3.587	1.42	0.118	3.8596
Up-mid-stream	SGCC	8.751	3.201	0.13	9.319
	Beijing University of Posts and Telecommunications	2.753	3.207	0.13	4.2286
	CMCC	3.933	1.536	0.13	4.2243
Mid-down-stream	SGCC	9.533	3.434	0.121	10.133
	Beijing University of Posts and Telecommunications	2.566	3.112	0.121	4.035
	CMCC	3.666	1.477	0.121	3.954

4 Conclusions

This paper uses Ucinet6.0 software to construct generic technological innovation cooperation network for China's electronic information manufacturing industry, and uses social network analysis method to analyze the network structure characteristics and network subject characteristics based on the industry chain, and the results show that in the cooperation, most innovation subjects tend to establish cooperative relations with familiar partners around them, showing the characteristics of strong relationship network. The network structure is relatively uniform in the early stage, and innovative subjects actively participate in cooperation, the gap in development makes it difficult to further share technical information, and the flow of key information is gradually difficult. Enterprises are the core innovation subjects of the network, and universities and research institutes gradually participate in the innovation cooperation of all links of the industry chain, and the industry chain is gradually opened up to promote cooperation and development. Therefore, the core innovation subjects should target the key links of the industry chain and the core generic technologies, and give priority to development to drive the development of small and medium-sized enterprises. All kinds of innovation entities should focus on strengthening generic technical cooperation, collaborative research and development, promoting the coordinated development of innovation chain and industry chain, and further enhancing the resilience of the industry chain. The government should give play to the leading role, improve the environment for cooperation in generic technological innovation, and promote the development of cooperation in generic technological innovation.

References

[1] Cen Jie, LI Zhangyan, Li Jing. Patent cooperation network and generic technology spillover[J]. Studies in Science of Science, 2021, 39(05): 882-891.

[2] Liu Yu, Kang Jian, Shao Yunfei. Triple helix evolution and motive force of industry generic technology collaborative innovation——an example of comparing bio-medical industry among Chengdu, Deyang and Mianyang[J]. Forum on Science and Technology in China, 2017(12):83-90.

[3] Li Lin, Guo Lihong, Yang Minli. Research on the Evolution of Transnational Cooperative Innovation Network and lts Influencing Factors: An Empirical Analysis Based on International Co-invention Patent Data[J]. On Economic Problems, 2021(09):119-129.

[4] Chen Wenjie, Zeng Deming, Chen Xiongxian. Analysis of Toyota's low-carbon vehicle technology collaborative innovation network map[J]. Science Research Management, 2015,36(02):1-10.

[5] Yang Chunbaixue, Cao Xing, Gao Yuan. A research on the evolution path and characteristics of the emerging technology cooperation innovation network[J]. Science Research Management, 2020,41(07):20-32.

[6] Zhang Shengjian, Hu Renjie. The Centrality Analysis of Enterprise Technology Innovation Cooperation Network[J]. Science and Technology Management Research, 2013,33(11):14-19.

[7] Liu Shengqi. Research on the evolution and innovation of the industry chain of contemporary electronic information manufacturing industry[J]. Practical Electronics, 2016(22):66.

[8] Luan Chunjuan. Emperical study on the measuring indicators of generic technology of emerging industries of strategic importance[J]. Forum on Science and Technology in China, 2012(06):73-77.

[9] Liu Huajun, Liu Chuanming, Sun Yanan. Research on the Spatial Correlation Network Structure of Energy Consumption in China and Its Effect.

[10] Wu Feifei, Han Chaoxi, Huang Lucheng. Analysis of the Characteristics of Integrated Circuit Industry R&D Cooperation Network——Based on the Perspective of Industry Chain[J]. Science & Technology Progress and Policy, 2020, 37(08):77-85.