Comparative Study on the Global Technological Competitiveness of China's Electronic Information Manufacturing Industry from the Perspective of Patent Citation

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Abstract. Electronic information products manufacturing (EIM) industry holds the key to intelligent transformation against the backdrop of a new round of industrial revolution. With patent citation as a research angle, this paper collects and collates the patent data of 24 home and abroad leading enterprises in EIM industry from 2005 to 2017, and studies their cross-reference relation to gain insights into the global technological competitiveness of China's EIM industry. The study shows that currently China's EIM industry is at a stage of technology absorption and standing at the periphery of global innovation network overall; networking and communication equipment manufacturers enjoy their marked competitive edge globally, while electronic parts and components are major weak spots of EIM industry. Therefore, in order to enhance the technological competitiveness of China's EIM industry, the author proposes three suggestions and countermeasures, namely, exploring new government investment incentive mechanism, encouraging leading enterprises to grow in both size and strength, and pushing for independent R&D of high-end chips.

Keywords: EIM; exploring new government investment incentive mechanism; pushing for independent R&D of high-end chips; studies cross-reference relation; global technological competitiveness.

1. Introduction

The EIM industry, as a strategic emerging industry, underpins China's transformation towards intelligent manufacturing. It is also a representative industry empowering China's deep participation in global competitions. The technological innovation capability of this industry is crucial to China's overall competitiveness in the new round of industrial revolution. Therefore, it is imperative to define the global technological competitiveness of China's EIM industry. Patents, as important outcomes of enterprises from technological innovation and the most effective technical information carrier, are valuable, rare, inimitable, and irreplaceable. Covering over 90% of latest technological intelligence globally [1], patents exist as an indicator measuring technological innovation. That is why using patent data to analyze technical competitiveness is of great reference value.

At present, most research results of using patent data to analyze technological innovation can be found in enterprises, industries, regions, and other realms. Ernst (2003) used patent intensity to measure enterprise technological competitiveness [2], Huang (2013) combined the number of patents with space to measure the competitiveness of innovation players in a comprehensive manner [3]; Li et al. (2016) built a technological competitiveness index system of industrial cluster in three dimensions including the number of patents, patent value and patent cooperation [4], Shen et al. (2018) examined and differentiated the subdivisions of China's pharmaceutical industry with modestly strong technological competitiveness through the distribution structure of patent application and paper publishing [5], Bao et al. (2018) used patent data to analyze how patents of different types affected the international competitiveness of varied intensive industries [6]; Zhu et al. (2018) compared the number of patent applied and its relative growth rate in Zhejiang and Guangdong to analyze the technological innovation trend in the two provinces [1]. Rare data about patent citation of enterprises can be found in current literature. Therefore, this paper is highly relevant and practical since it studies the global technological competitiveness of China's EIM industry by comparing and analyzing the patent citation of leading enterprises at home and abroad.

2. Design of Research Plan

2.1. Selection of Sample Enterprises

First, according to the manufacturing industry classification stipulated in the Industrial Classification for National Economic Activities (GB/T 4754-2017) of 2017, the author classified the EIM industry into four subdivisions, i.e. information communication, electronic parts and components, networking and communication equipment, and computer and office equipment manufacturing; then, considering the prime operating revenue of enterprises, the author selected the top 3 leading domestic enterprises and their global counterparts in the above-mentioned sectors from Fortune Global 500 and other rankings, and finalized 24 sample enterprises, namely the most representative 11 domestic enterprises and 13 global ones.

2.2. Data Source

The patent data used in the paper came from Derwent Innovations Index. The database contains cited patent search, and features unified data standard and specifies patentee code for each patentee. Therefore, it is more accurate compared with Ovid, SooPat and other databases. Enterprises with standard code were retrieved with patentee name + patentee code, and those without standard code were retrieved with patentee name; through trial retrieval, the author found that the number of patents before 2005 was small. So, the author defined retrieval time as 2005-2017 and conducted analysis while considering the publication time of patent application.

2.3. Building of Patent Citation Relation Matrix

While the number of cited patents reflects patent quality, patent citation relation among patentees reflects the type of enterprise technological innovation and knowledge diffusion. In order to analyze the technical position of an enterprise in the entire network and the technology competition structure among enterprises, the author built an enterprise-based patent citation adjacent matrix in line with the patent citation relations among enterprises. In the matrix, the rows and columns represent "actors" of the network and the *Eij* value corresponding to enterprises *Ei* and *Ej* represents the citation of enterprise *Ei's* patent *by* enterprise *Ej*.

3. Empirical Result Analysis

3.1. Calculation of Patent Citation Centrality

Degree centrality is used to measure the closeness of a node to the network central position based on the number of links from the node in the network to other "actors". The higher the value is, the closer the position of an enterprise is to the central position of the system. As the paper studies directed citation network, the author classified degree centrality into out-degree and in-degree, which stand for the degree of an enterprise in outputting and inputting patents respectively. Meanwhile, in order to compare the centrality of different nodes, the author used the relative centrality defined by Freeman, namely the ratio of the absolute centrality to the maximum possible degree of a node. The expression is: $C'_{RD(X)} = \text{in}-\text{degree of } X + \text{out}-\text{degree of } X/(2n-1)$, with *n* being the scale of a network. Finally, the author imported the built patent citation relation matrix of sample enterprises into UCINET, and calculated the Nrm-OutDeg and Nrm-InDeg of sample enterprises, with results as shown in Table 1.

Table 1. The Nrm-OutDeg and Nrm-InDeg of patent citation of sample enterprises

Subdivision	Enterprise Name	Nrm-OutDeg	Nrm-InDeg	Subdivision	Enterprise Name	Nrm-OutDeg	Nrm-InDeg
Information Communication	CORNING	0.542	0.664	Networking and Communication Equipment	**HUAWEI**	**6.718**	**7.091**
	FURUKAWA	0.365	0.275		**ZTE**	**4.877**	**5.771**
	FIBERHOME	**0.180**	**0.214**		ERICSSON	3.921	2.214
	YOFC	**0.039**	**0.034**		NOKIA	3.529	1.582
	PRYSMIAN	0.022	0.028		CISCO	1.961	1.945
	HTGD	**0.007**	**0.011**	Computer and Office Equipment Manufacturing	**TCL**	**0.918**	**2.426**
Electronic Parts and Components	INTEL	4.075	2.933		HP	2.402	1.841
	QUALCOMM	2.928	4.025		APPLE	1.458	2.421
	TSMC	**1.110**	**1.070**		**LENOVO**	**0.664**	**1.081**
	SMICS	**0.424**	**0.585**		DELL	0.564	0.407
	SHHIC	**0.281**	**0.325**				
	Onex	0.048	0.027				
	FLEXTRONICS	0.036	0.096				
	XINCHAO	**0.033**	**0.035**				

Note: The enterprise names in bold are Chinese sample enterprises, including TSMC.

3.2. Analysis of Patent Citation Centrality

(1) Currently China's EIM industry is at a stage of technology absorption and standing at the periphery of global innovation network overall. The analysis of data shown in Table 1 indicates that the sum of the Nrm-InDeg of the 11 Chinese sample enterprises is 18.643, markedly higher than the sum of Nrm-OutDeg, which is 15.251, accounting for 50.25% and 41.11% of those of the 24 sample enterprises respectively. Except YOFC and TSMC, the Nrm-OutDegs of the rest nine sample enterprises are all lower than their relative in-degrees, and 82% enterprises are at the stage of technology import. That means that when it comes to foreign patents, China's EIM industry achieves higher input degree than output degree, and the whole industry is at a stage of technology absorption. The patent citation network graph of sample enterprises drawn with the built-in NETDRAW of UCINET is shown as follows. In the graph, the 24 sample enterprises are classified into three layers based on the number of their cited patents. The enterprise at the core layer is NOKIA, the enterprises at the middle layer include ERICSSON, CISCO and other seven, and the outer layer consists of ONEX, DELL and other 12 enterprises. Only four Chinese enterprises, HUAWEI, ZTE, LENOVO and TSMC, are at the middle layer of the innovation network; the rest seven are at the outer layer, accounting for 63% of the Chinese sample enterprises.

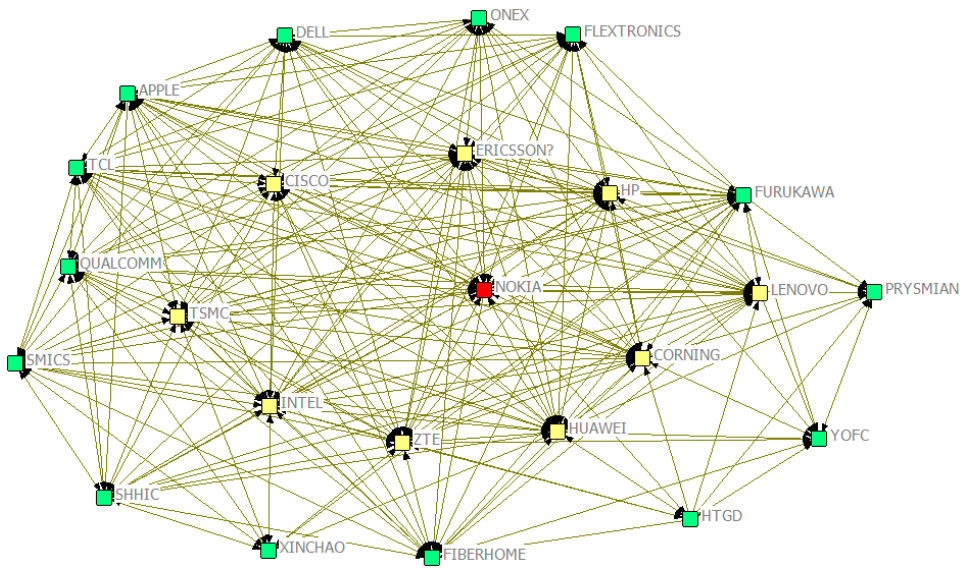

Figure 1. The patentee citation network of sample enterprises

(2) Leading enterprises in networking and communication equipment manufacturing subdivision enjoy marked competitive edge globally. In this subdivision, the sum of Nrm-InDeg of HUAWEI, ZTE, and TCL is 12.513, and their sum of Nrm-OutDeg is 15.288, accounting for 57% and 73% of the total in this subdivision respectively. Particularly, HUAWEI is ranked the 1st place and ZTE the 2nd place among the sample enterprises in terms of the Nrm-OutDeg and relative in-degree, far higher than the 3rd performer. That means that HUAWEI and ZTE are leading enterprises with world-leading techniques in this subdivision. According to reports in HUAWEI website, as of December 31, 2017, the company has applied for a total of 64,091 Chinese patents and 48,758 foreign patents, with over 90% being patents for invention; its patents have been cited 90,179 times, and 14,847 core patents have been cited for more than three times, making HUAWEI a paradigm as China competes deeply in the global arena.

(3) Electronic parts and components are major weak spots of China's EIM industry. There are four Chinese sample enterprises in this subdivision. The sum of their Nrm-OutDeg and the sum of their Nrm-InDeg only account for 21% and 22% of the total respectively, and three of them are at the periphery of global innovation network. That means that this subdivision in China still lags behind global players in terms of technology absorption and output. Integrated circuit is a representative product of this subdivision, as well as a "bottleneck" holding back China's EIM industry. According to the data released by the General Administration of Customs of the People's Republic of China, the year 2017 witnessed China's import of 377 billion integrated circuits, valuing USD 260.1 billion, nearly twice of the value of imported crude oil as an import product entailing the largest amount of foreign exchange.

4. Conclusion and Suggestions

4.1. Research Summary

First, currently China's EIM industry is at a stage of technology absorption and standing at the periphery of global innovation network overall. The industry faces deep-rooted and structural problems, such as scattered resource allocation and too large share of processing trade.

Second, leading enterprises in networking and communication equipment manufacturing subdivision enjoy marked competitive edge globally. Down the road, this subdivision will embrace better development opportunities amid the new generation mobile communication technology, cloud computing, big data, and other national strategies.

Third, electronic parts and components are major weak spots of China's EIM industry. This subdivision is subject to the control of others in terms of key technologies and core components. This subdivision is still at the lower and middle end of value chain, and there is still large room for innovation and transformation.

4.2. Suggestions

From the perspective of government departments, this paper puts forward the following Suggestions:

(1) Exploring new government investment incentive mechanism. The author suggests governments further improve public service platform and offer more protection towards patent for invention. Governments are also suggested to rebalance their financial investment structure, increase the share of sci-tech input in fiscal expenditure, and optimize performance evaluation and supervision system.

(2) Encouraging leading enterprises to grow in both size and strength. The author suggests governments accelerate the deep integration between the EIM industry and IT application by leveraging the basic advantages of existing industries. Governments are also suggested to steer China's EIM industry toward the networked, digital and intelligent development. These efforts will be made to shape an industrial system featuring top-notch structure and strong competitive edge in high-end areas in pursuit of development in clusters.

(3) Pushing for independent R&D of high-end chips. Governments should play a leading role in defining the R&D of domestic high-end chips as a national security priority, building confidence and making sustained investment; they should tap the potential of the National Integrated Circuit (IC) Innovation Center as a platform; meanwhile, they should shape an IPR protection and business environment enabling innovation and R&D.

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