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Chapter 2

Technological Specialization: The Case of China's Construction Machinery Industry*

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Abstract: This report shows the technological position of firms in an industry, and the impact on the whole industry as a result of increasing intellectual properties with a case of Chinese construction machinery manufacturers. Although firms are doing R&D for product differentiation and filing many intellectual properties, but because a product consists of multiple technologies there are many options for their technological position in terms of technological fields. Firstly, we show that firms tend to diversify technology in terms of technological fields, but at the same time, focus on some technological fields. The technologies in the industry are specialized for products by combining the technologies for the inherent basic functions of the products and the various technologies for increasing the value of products. Secondly, we show that technological information opened as intellectual property can diffuse to the whole industry. Firms can learn the technological stock of each other. Consequently, technological differentiation and learning by firms are driving technological specialization for producing attractive products across the whole industry.
Key Words: Intellectual property, technological distance, specialization, China

1. Introduction

Innovation hubs are spreading throughout the world. Previously, innovation activities

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were centered mainly in the traditional developed countries, such as the European countries, the United States, and Japan. However, with the rise of many emerging countries and the Fourth Industrial Revolution, the wave of innovation activity is spreading to China and other East Asian countries and areas.

As a result, intellectual properties are increasing along with increasing research and development (R&D) activities in East Asia. Of course, not all the results of innovation activities become intellectual property rights. Some are not made public and are kept as trade secrets. In recent years, Internet-related business model innovations have increased in particular. Although we have to notice about that, however, intellectual properties remain useful information for technological analysis.

We show how Chinese firms have formed technological positions with the increase of intellectual properties. Much has been studied about the relationship between performance and the patents by firms (Hall et al., 2005). However, because a product generally consists of multiple related technologies and the business structure and product lineup of each firm are different among firms, even if they belong to the same industry, so the technological positions also differ from firm to firm. Moreover, because firms cannot obtain all the related technologies for business within a short period of time, the process of accumulating technologies can also vary among firms.

This chapter shows the following concerning the intellectual properties of China’s construction machinery industry. Firstly, firms are improving their technological competitiveness by diversifying technologies in terms of technological fields, and by focusing on some technological fields for the basic functions of products. Secondly, firms can learn about the technologies from existing technological information opened as intellectual properties. Consequently, we show an example of technological differentiation and learning by firms in an emerging country.

The structure of this chapter is as follows. Section 2 introduces the approach used for our analysis. Section 3 compares the technological distance among Chinese construction machinery firms. Section 4 compares them with the previous technological distance. Finally, we summarize and conclude the analysis.

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2. The Approach: Technological Information and Distance

2.1. Technological Information

In this study, we use the Orbis Intellectual Property provided by the Bureau van Dijk for intellectual property and firms' information.[1] The Orbis Intellectual Property combines Bureau van Dijk's accounting information of firms, Orbis, and Lexis Nexis's intellectual property information. The firms and intellectual property information are identified by a unique code for each firm given by the Bureau van Dijk.

We focus on China's construction machinery industry. The industry is specifically the "Construction Machinery Manufacturing" of the North American Industry Classification System (NAICS) for 2017 (NAICS 2017). The reasons for choosing this industry are as follows. Firstly, there are some major Chinese firms that have gradually developed overseas markets in the construction machinery industry. Since technological competitiveness is often required for overseas markets, we can find the trend of some firms that are trying to improve their technologies. Secondly, the product markets of major firms in the industry are relatively overlapping. Because an industry in the industrial classification generally consists of firms in various product markets, it is often difficult to classify firms into an industry in terms of the competition relationship in a particular product market.

The conditions of intellectual properties in this chapter are as follows. Firstly, we use patent applications and utility models as of January 10, 2020.[2] Since the number of utility models has often increased first in China, therefore those were also included here. Secondly, we use intellectual properties filed by indigenous Chinese firms in China. Therefore, firms which have foreign capital as the ultimate owners are excluded. However, if firms are owned by a Chinese ultimate owner firm are established in Hong Kong or tax havens, then the firms are included as indigenous Chinese firms. Thirdly, patents filed jointly by firms are treated as if each firm has filed one patent application.

Consequently, the number of intellectual properties and firms counted based on the intellectual properties we use here are 49,877 intellectual properties and 1,162 firms, respectively. The number of patent applications and that of utility models are quite the same with 24,199 and 25,678, respectively. However, there were more utility models

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[1] Bureau van Dijk (the Netherlands) became part of Moody's Analytics (the U.S.) in 2017.

[2] Some patent applications are registered as granted patents through examination.

until 2014. On the other hand, the ratios by technological field are relatively similar.

2.2. Technological Distance

In order to show the difference in technology among firms, we use the technological distance used by Jaffe (1986). Technological distance is a concept that indicates the difference in the technological position of each firm in terms of the technological field. Here, the difference in technological position of each firm is measured based on the technological field of intellectual properties.

The technological distance can be defined as follows. If the number of intellectual properties applied by Firm i in a technological field k is F_{ik}, $\mathbf{F}_i = (F_{i1}... F_{in})$ represents the technological position of the firm. Then, the technological distance D between Firm i and Firm j is formulated as follows (Jaffe, 1986; Yamada, 2009).[3]

$$D_{ij} = \mathbf{F}_i\mathbf{F}_j'/[(\mathbf{F}_i\mathbf{F}_i')(\mathbf{F}_j\mathbf{F}_j')]^{1/2}$$

We use the international patent classification (IPC) for the technological field. The IPC is a hierarchical system based on the technological content of the patents. An IPC code(s) is assigned to each intellectual property. We mainly use the second layer (Class) of the five layers. If firms have a similar ratio of the number of intellectual properties in each field, the technological distance is close to 1; otherwise, it is close to 0.

The technological distance is often used to measure the distance between each firm, but here, we measure each firm's distance from a fictitious benchmark firm which files one intellectual property in every technological field, that is, $\mathbf{F}_{benchmark} = (1, 1, 1, \ldots, 1)$. However, it should be noted that "all fields" here are all the fields applied for by Chinese construction machinery firms, not those of the IPC. Therefore, since the technological position of the benchmark firm is the state that the firms apply equally to all the technological fields, if it is general that the number of intellectual properties differs depending on the technological fields, there is a possibility that the distance of each firm to the benchmark will not be as close to 1.[4]

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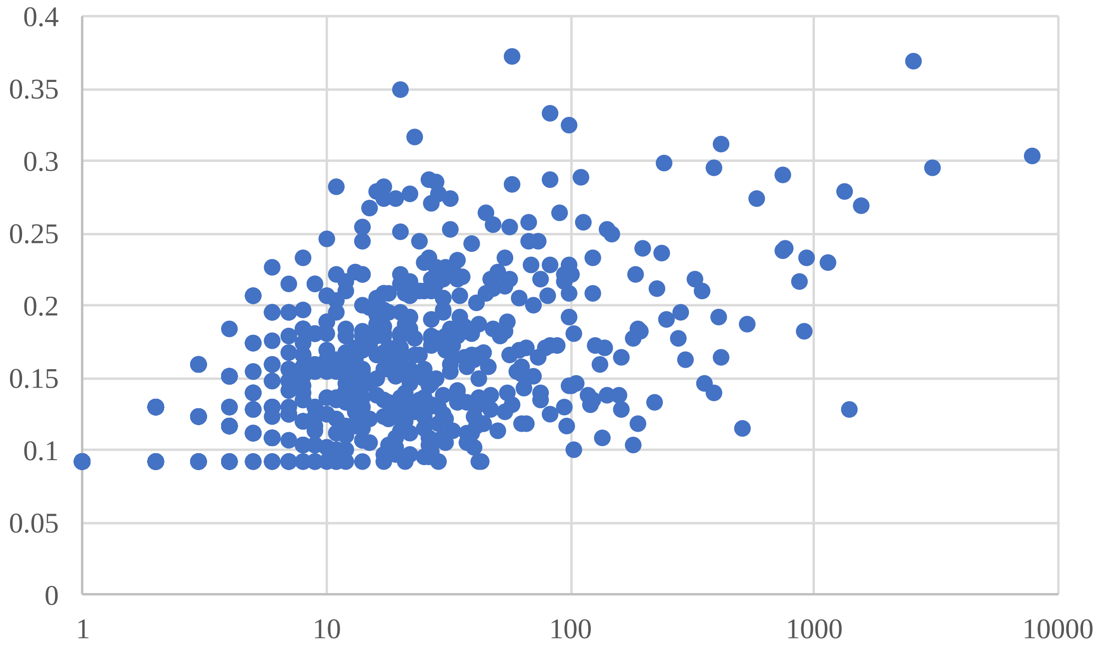
[3] There is a variety of technological distances (Bar and Leiponen, 2012).

[4] In this case, the differences depending on the technological fields cannot be reflected in the technological distance. For example, the technological distance of a firm that has no intellectual

3. Technological Distance: A Comparison Among Firms

Figure 1 shows the relationship between the technological distance of Chinese construction machinery firms to the benchmark firm, and the number of intellectual properties of the firms. The numbers on the horizontal axis are logarithmic values. The technological distance closest to 0 is 0.09, and one intellectual property is a case of 0.09.

Figure 1: Technological Distance and the Number of Intellectual Properties



Source: Author's creation based on Orbis Intellectual Property.

We can find the following two points from the diagram. Firstly, the diagram shows that technological distance tends to move away from 0 as the number of intellectual properties increases. Since the benchmark firm has one intellectual property in every technological field, the technological distance moves away from 0 because firms are more likely to develop technologies in more technological fields as they apply more intellectual properties.

Secondly, on the other hand, even if the number of intellectual properties

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property only in one different technological field, and the same number in the rest of the technological fields, becomes the same as each other.

increases, the technological distance is around 0.30, that is, far from 1.00. Also, the technological distance of the total number of all the firms is 0.40. Therefore, even if the number of technological fields that firms file increases, the number of intellectual properties in each technological field is significantly different. It means that the technological position of the benchmark firm is a special case of the perfect equality among the technological fields.

Consequently, the two facts indicate that firms tend to diversify technologies in terms of technological fields, but the number of intellectual properties in some fields is very large. Both elements of the technologies are important for firms: one is the technologies for the basic functions inherent in the products; the other is the various technologies for improving the products' value and enhancing the product lineup. In other words, firms are improving their technological specialization as a technological structure. While specialization through the division of labor can increase productivity and change the industrial structure (Ros, 2013), firms do not focus on one technological field alone.

The total number of intellectual properties in China also shows unevenness in terms of the technological fields. The number of technological fields is 117, but the top 10 fields account for 65.7% of the total number. Intellectual properties concentrate in the technological fields related to construction operations (B66, E02, E01, E21, B65), and those related to basic elemental technologies, such as engineering elements (F16) and hydraulic cylinders (F15).

Table 1: The Number of Intellectual Properties by Technological Field

IPC	Description	Patents
Total	—	49,877
B66	Hoisting; Lifting; Hauling	5,949
E01	Construction of roads, railways, or bridges	4,088
E02	Hydraulic engineering; Foundations; Soil-Shifting	4,045
E21	Earth or rock drilling; Mining	3,881
F16	Engineering elements or units; General measures for producing and maintaining effective functioning of machines or installations; Thermal insulation in general	2,954
B65	Conveying; Packing; Storing; Handling thin or filamentary material	2,797
F15	Fluid-Pressure actuators; Hydraulics or pneumatics in general	2,604
B23	Machine tools; Metal-Working not otherwise provided for	2,309
B60	Vehicles in general	2,221
G01	Measuring; Testing	1,904

Source: Same as for Figure 1.

Although the content of the technological positions differ from firm to firm, there is also something in common. Table 2 shows firms with more than 1,000 intellectual properties (Table 2). We can find major Chinese construction machinery firms, such as Zoomlion Heavy Industry Science and Technology (中联重科; Zoomlion), XCMG Construction Machinery (徐工集团; XCMG), Sany Heavy Industry (三一重工; Sany), and Shantui Construction Machinery (山推; Shantui). The technological distance of them is around 3.0. Each firm produces excavators, bulldozers, etc., even though the product lineups differ partially. There is a two-way relationship between competition and technology development, so it is difficult to identify specific factors of R&D activities (Belleflamme and Peitz, 2010), but there is a correlation that large firms have many intellectual properties and similar technological positions.

Table 2: Firms with More Than 1,000 Intellectual Properties

Firm	Total (patents)	Distance	Sales (th USD)	# of employees (persons)
Zoomlion Heavy Industry Science and Technology	7,889	0.30	4,187,509	15,121
XCMG Construction Machinery	3,068	0.29	6,189,296	14,318
Sany Heavy Industry	2,539	0.37	7,881,235	17,383
Shantui Construction Machinery	1,551	0.27	1,000,933	5,390
China Railway Engineering Equipment Group	1,384	0.13	603,690	1,240
Dalian Huarui Heavy Industry Group	1,331	0.28	940,319	5,588
China First Heavy Industries	1,147	0.23	1,503,140	7,858

Note: Sales and # of employees are in 2018.

Source: Same as for Figure 1.

The major businesses of the other three firms, China Railway Engineering Equipment Group (中铁装备; CREG), Dalian Huarui Heavy Industry Group (华锐; Huarui), and China First Heavy Industries (中国一重; CFHI) are partially the same and partially different with the above four firms. CREG conducts underground construction under the China Railway Engineering Group. Huarui and the CFHI are heavy machinery manufacturers including construction machinery. Although the technological distance of CREG is relatively far from 0.30, the technological distance of the heavy machinery manufacturers are close to it.

These seven firms tend to file intellectual properties in more technological fields as the number of applications increases, but nearly half the number of intellectual properties is concentrated in a few top technological fields (Table 3). Moreover, the top five fields largely overlap with the major technological fields for construction machinery manufacturing in Table 1.[5] Although Chinese firms depend heavily on foreign firms for core components such as engines and hydraulic cylinders (Jin, 2013), and the quality of the intellectual properties is required to be analyzed, however, it shows that these four firms have also applied for many intellectual properties in technological fields related to the basic functions of construction equipment. On the other hand, diversifying technologies have been increasing the sophistication of the products. The objectives include improving the method of processing materials, work

[5] The top five fields of CREG overlap with the technological fields in Table 1, but the technological distance is different from those of the other six firms because the number of the top fields is particularly large.

efficiency, safety, and so on.

Table 3: Technological Positions of Firms with More Than 1,000 Intellectual Properties

Items	Zoomlion	Items	XCMG	Items	Sany	Items	Shantui
Total	7,375	Total	3,051	Total	2,169	Total	1,545
Fields	73	Fields	59	Fields	54	Fields	52
% of Top 5	53.0	% of Top 5	62.9	% of Top 5	45.5	% of Top 5	61.6
IPC		IPC		IPC		IPC	
B66	1,770	B66	646	E01	218	E02	415
F15	628	E02	379	B66	208	F16	228
E01	616	E01	332	B28	198	B60	110
F16	503	F15	288	B60	182	B62	100
B60	391	B60	274	F15	181	B23	99

Items	CREG	Items	Huarui	Items	CFHI
Total	1,350	Total	1,320	Total	1,146
Fields	36	Fields	47	Fields	38
% of Top 5	85.4	% of Top 5	63.3	% of Top 5	65.0
IPC		IPC		IPC	
E21	956	B66	274	B21	412
G01	82	B65	264	B23	144
F16	44	C10	133	B22	82
B65	38	B22	85	G01	66
F15	33	F16	79	C21	41

Source: Same as for Figure 1.

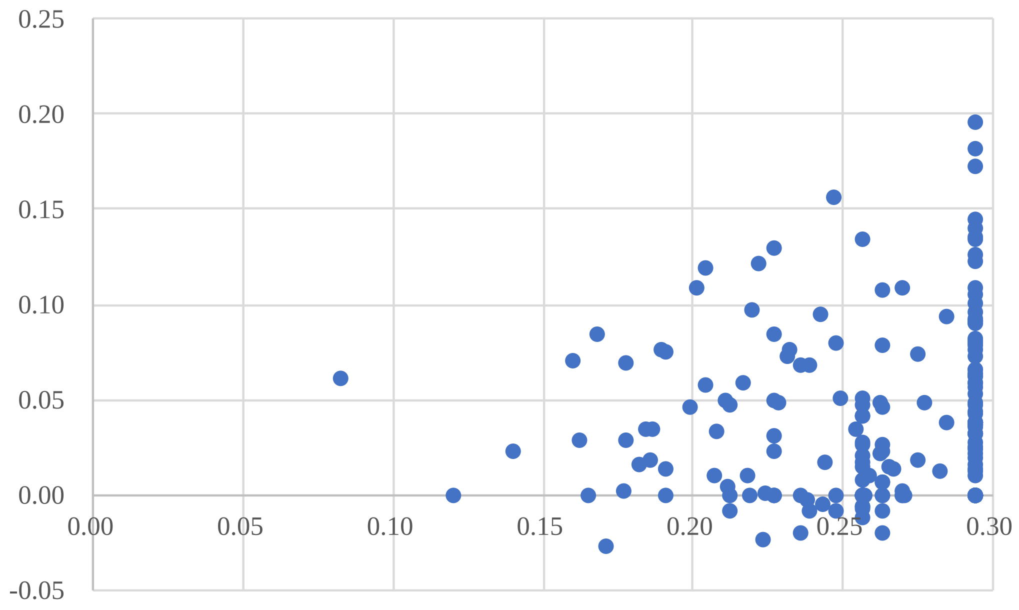
In addition to these major finished product manufacturers, the technological position of other small- and medium-sized and component firms also have a similar tendency. Firms are likely to diversify technologies and focus on some technological fields. Therefore, even with a few intellectual properties, the number of technological fields is generally less than that of the intellectual properties. Although not only technological distance but also the increase in intellectual properties is important, we can find that buds that form the technological structure with these two technological elements are emerging.

4. Relationship with the Technological Stock: A Comparison with the Past

Firms can learn technologies from other firms from technological stock. If firms learn from past intellectual properties in the construction machinery industry, the technological distance of each firm in the industry may approach that of all the past intellectual properties.

Figure 2 shows the relationship between the technological distance of each firm from the total number of intellectual properties as of 2009 (the horizontal axis), and the moving distance of each firm between 2009 and 2019 (the vertical axis). Here, firms that have never applied for an intellectual property until 2009 are excluded in the diagram, because they did not have a technological distance in 2009.[6] This is a comparison of the technological distance before and after the early 2010s, when the number of intellectual properties increased rapidly. The technological distance of all the intellectual properties in 2009 was 0.39 (the total number of intellectual properties was 2,573), and that in 2019 was 0.40 (the total number is 49,887 as shown in Table 1). Therefore, although the number of intellectual properties has increased sharply, the past and current technological distances of all the intellectual properties are almost the same.

Figure 2: Difference from the Total Number in 2009 and Moving Distance between 2009 and 2019



Source: Same as for Figure 1.

[6] The technological distances of the firms with no intellectual properties as of 2009 moved by the distance between 0.09 to 0.37.

The diagram shows that, although there is some width in the moving distances, the longer the differences, the longer are the moving distances. The technological distance of firm with one intellectual property was only 0.09 in 2009, but that of some reached around 0.29, while that of some show no change. On the other hand, when the difference between the technological distances of all the intellectual properties as of 2009 and each firm is small, there is a possibility that the moving distances decrease.

Firms can learn technologies from the knowledge information opened as intellectual properties. As a result, the technological position of each firm can become similar in terms of technological fields. The greater the difference, the more difficult it may be to learn. However, since we focus on firms that have one or more intellectual properties, there is no doubt that the firms here have the capability for technological development as of 2019.

5. Conclusion

This report shows the technological position of firms in one industry and the impact on the whole industry as a result of increasing intellectual properties with the example of Chinese construction machinery manufacturers. Although firms are doing R&D for product differentiation and filing many intellectual properties, because a product consists of multiple technologies, so there are many options for their technological position in terms of the technological fields.

The following are indicated. Firstly, firms tend to diversify technologies in terms of technological fields, but at the same time, focus on some technological fields. The technologies in the industry are specialized for products by combining the technologies for the inherent basic functions of the products and the various technologies for increasing the sophistication of the products. Secondly, the technological information opened as intellectual properties can diffuse to the whole industry. Firms can learn from the technological stock of each other.

Consequently, the technological differentiation and learning by firms are driving technological specialization for producing attractive products as the whole industry in comparison with other industries. Even though the technological positions become similar in terms of the technological fields as the intellectual properties increase, each intellectual property is a source of product differentiation against competitors. On the other hand, the publication of intellectual properties gives other firms information as to where the technological problems are and how to solve them. The combination of both differentiation and learning has led industrial differentiation in terms of technologies across the whole industry.

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