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The Patterns of Patents in China

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Contents

Tables

Figures

ABSTRACT

Innovations are a key driver of long-term economic growth. There has been an explosion of patent filings in China in the past three decades. But empirical studies on the pattern of innovations at the firm level are rather scant primarily due to lack of firm-specific patent data. We have made concerted efforts to match Chinese patent data with a large firm-level database. The matched dataset enables us to examine the patterns of patents at the firm level. Our analysis has revealed several interesting patterns: (1) domestic firms have become increasingly more innovative in terms of patent application; (2) private firms, rather than state-owned enterprises, have been the engine of innovation; (3) rising wages have propelled labor-intensive sectors to become more innovative; and (4) in response to increasing sex ratio imbalances, firms in female-intensive industries have exhibited more innovations than those in male-intensive industries.

Keywords: patent, innovation,

JEL classification: O12, O31, O53

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1. INTRODUCTION

China has achieved phenomenal economic progress with an average annual GDP growth rate near 10 percent since 1978. During this period, the number of patent filings in China has grown even faster. In 1990, there were only 41,468 patent applications. But by 2012 this number had spiked almost 50-fold to 2,050,649. The number of invention patents, arguably the most important one among three types of patents, surpassed the number in the United States in 2011 (WIPO, 2012). China has become the largest recipient of patent filing globally. Despite the record growth, little is known about the evolutionary patterns and structures of Chinese patents, in particular at the firm level, largely due to lack of firm-level patent data.

Innovation is a key driver of long-run economic growth (Schumpeter 1934; Aghion and Howitt 1992). It is particularly important for middle-income countries like China. In the past several decades, China has adopted an open-door policy to attract foreign investment and technologies. Chinese firms have quickly absorbed, imitated, and modified the existing foreign technologies, catching up with the global technologies frontiers. The massive inflow of foreign capital and technology has also brought about hundreds of millions of jobs. However, in the past decade, the seemingly unlimited supply of labor has been exhausted, resulting in escalation of real wages (Zhang, Yang, and Wang 2011; Huang and Jiang 2010). Facing rising wages, Chinese firms have to invest more in technologies to substitute the increasingly more expensive workers. As China becomes a middle-income country and narrows its gap with technological frontiers in developed countries, simply grabbing existing technologies on the shelf of developed countries is no longer a viable option. Instead it has to count more on indigenous innovations to upgrade its industries (Feng and Yao 2014; Lin 2012; Zhuang, Vandenberg, and Huang 2012).

Patents are an integral part of modern innovation systems. The patent system is one of the most important institutions to protect intellectual property rights and encourage innovation in a modern economy. It is expected that innovations in the form of patents will play a greater role in propelling Chinese economic growth in the future as China enters an era of rising wages. To better foretell future patent growth, it is critical to understand the historical patterns of patent development. However, due to data constraints, studies on the historical patterns of Chinese patents, particularly at the firm level, are rather scarce.

The economic literature on the use of intellectual property in China is much more limited than the legal literature. A few theoretical articles study the optimal patent protection in China (Kou and Zhou 2011; Xu 2010; Dong and Wang 2007; Kou 2004). Most empirical studies use secondary data, such as aggregate data at the provincial or industry level (Hu and Jefferson 2009; Cheung and Lin 2004) or data of publically listed companies (Li, Hong, and Wu 2012; Choi, Lee, and Williams 2011; Lin, Lin, and Song 2010). A few studies based on disaggregated data are limited to only a particular region (Qin, Zhou, and Yin 2012; Dobson and Safarian 2008; Zhu and Xu 2003). A few studies examining the knowledge spillover effect of foreign direct investment have used individual patent data (Wu and Mathews 2012; Awokuse and Yin 2010; Cheung and Lin 2004).

None of the above studies, however, has examined patents at the firm level. Some basic questions regarding Chinese patents remain to be answered. To name a few, how important is the role of foreign firms in driving the trend of Chinese patents? Are the state-owned enterprises (SOEs) or privates ones more innovative? In which places or industries are firms more productive in terms of patent applications? Have firms in labor-intensive industries produced more patents than those in capital-intensive industries in response to rising real wages?

To answer these questions, we made concerted efforts to match Chinese patent data with the annual survey of industrial enterprises in China (ASIEC). The database covers all the SOEs and above-scale private firms with sales exceeding 5 million yuan from 1998 to 2009. The patent database contains all patents granted between 1985 and 2009. The merged firm patent database enables us to study the historical patterns of China's patents.

This paper also contributes to the general literature on patents in developing countries. Although there is a large strand of economic literature studying patents and innovation in developed countries, the research on developing countries is much more scant (Gonzalez et al., 2013). There are at least two explanations for the disparity. First, innovation is a capital-intensive activity. In the early stage of development, due to lack of capital resources, it makes more economic sense for developing countries to import and imitate some of the outdated technologies that have fallen into disuse in developed countries. Consequently, promoting the development of patents is not high on the policy agenda in developing countries. Second, lack of high-quality patent and firm data is pandemic in developing countries, hindering researchers from conducting empirical investigations on patents in developing countries.

This paper is structured as follows. Section 2 introduces China's patent system and presents some basic stylized facts about China's patents. Section 3 discusses the methods to match the two databases. Some facts derived from the merged database are listed in section 4. A concluding section summarizes the main findings.

2. STYLIZED FACTS ABOUT PATENTS IN CHINA

Brief Introduction of the Patent System in China

Intellectual property protections involve at least three aspects: patents, trademarks, and copyrights. The intellectual property system in China is administered by several institutions, with the patent system administered by the State Intellectual Property Office of the People's Republic of China (hereinafter referred as SIPO), trademarks by the Trademark Office of the State Administration for Industry and Commerce, and copyrights by the National Copyright Administration.

China established the Patent Office, which later became SIPO, in 1980. The Patent Law was passed on March 12, 1984, and put into effect on April 1, 1985. SIPO began to accept patent filings in 1985. Compared to developed countries', China's patent history is rather short. Despite the late start, China joined the Paris Convention, an international treaty with respect to intellectual property, in 1985.

The Patent Law has been amended three times—September 4, 1992; August 25, 2000; and December 27, 2008—since its implementation. The Patent Law set clear rules for patent applications, examinations, approvals, protection scopes, and patent prosecution. SIPO is the sole authority to process patent applications in China.

In addition to the Patent Law, the state passed the Implementing Regulations of the Patent Law of the People's Republic of China (hereinafter referred as Implementing Regulations). According to the regulation, patents in China are classified into three types: invention, utility model, and design. Invention patents encompass new technical solutions relating to a product, a process, or improvement; utility model patents represent new technical solutions relating to the shape, the structure, or their combination, of a product, which are mainly for practical use; design patents cover new designs in relation to shapes, patterns, colors, or their combination, of a product. They create an aesthetic feeling and are primarily for industrial applications.

The duration of protection for invention patents is 20 years, while the duration for utility model and design patents is 10 years, effective from the application date.

China Patent Database

We purchased all the records of patents approved as of May 1, 2014, from SIPO. Our patent database includes all the patents approved as of May 1, 2014, and applied as of December 30, 2009. The database contains 4,060,392 observations, including 1,097,000 invention patents, 1,620,069 utility model patents, and 1,343,323 design patents. A typical entry of patent includes the following information: applying number, patent name, applicant, inventor, applying date, publishing date, granting date, main International Patent Classification (IPC) number, filing agent's name and institution, applicant address, patent origin (provinces in China or other countries), and a short description of the patent.

Some variables need more explanation and clarification. *Applicant* is different from *inventor* in that the former owns the patent while the latter invents the patent. Applicants can be individuals, firms, or institutions, whereas inventors must be individuals. *Applying date* is the date of filing patent application. Only an invention patent has a *publishing date* because an invention patent has to be published within 18 months of its submission. Afterward, it has to undergo substantial examinations. The patents of utility model and design are directly granted and published after preliminary examination. Generally speaking, invention patents embody more technological components than utility model and design patents.

According to IPC, all patents could be classified into eight major categories: human necessities; performing operations and transporting; chemistry and metallurgy; textiles and paper; fixed constructions; mechanical engineering, lighting, heating, weapons, and blasting; physics; and electricity. There are subcategories in each major category. One patent can belong to more than one category. The first category is the most relevant and is called *main IPC number.*

Applying patents is a tedious process involving heavy professional work. So some patent applicants hire agents to apply on behalf of them rather than file by themselves. For those entries, the information about filing agent is also displayed. The patent data reveal information about origins of the applicants, that is, province codes for domestic applicants and country codes for foreign applicants.

Several General Trends of Chinese Patents

In this subsection we present some trends in Chinese patents. It takes time to process patent applications. A patent can be granted one year, two years, or even longer after its submission. We use two yardsticks to illustrate the trend of Chinese patents—the number of patent applications per year and the number of granted patents according to the year of submission.

Let's use an example to illustrate the concepts of the three variables. Suppose 1,000 patent applications in total are submitted in year T. The number of patent applications in year T is 1,000. From the 1,000 patent applications, 50 patents are granted in year T, 200 patents are granted in year T + 1, 320 patents are granted in year T + 2, and 430 applications are rejected. The total number of granted patents corresponding to the application year T is 570.[1] This represents the number of eventually granted applications submitted in year T. We define the patent approval rate as the ratio of the number of granted patents and the application number corresponding to the same year.

Table 2.1 presents the overall trend of patents applied. As shown in Table 2.1, the application number in China increased rapidly between 1985 and 2012. The annual growth rate of patent application for the whole period averaged at 20 percent, about twice the annual GDP growth rate in the same period. Notably, the annual growth rate accelerated to 28 percent in the last period of 2005–2012. Initially design patents accounted for only 4 percent in 1985. By 2012, the share of design patents had reached 32 percent of total patent filings, reflecting explosive growth.

Table 2.1 Number of patent applications (1985–2012)

Year	Total	Invention (%)	Utility model (%)	Design (%)	Foreign (%)
1985	14,372	60	36	4	35
1986	18,509	43	52	4	26
1987	26,077	31	64	5	17
1988	34,011	28	66	6	16
1989	32,905	29	63	8	17
1990	41,469	24	67	9	12
1991	50,040	23	67	11	9
1992	67,135	21	66	12	8
1993	77,276	25	61	13	12
1994	77,735	25	59	17	13
1995	83,045	26	53	21	17
1996	102,735	28	48	24	20
1997	114,208	29	44	27	21
1998	121,989	29	42	28	21
1999	134,239	27	43	30	18
2000	170,682	30	40	29	18
2001	203,573	31	39	30	19
2002	252,631	32	37	31	19

[1] 570 = 50 + 200 + 320.

Table 2.2 Continued

Year	Total	Invention (%)	Utility model (%)	Design (%)	Foreign (%)
2003	308,487	34	35	30	19
2004	353,807	37	32	31	21
2005	476,264	36	29	34	20
2006	573,178	37	28	35	18
2007	693,917	35	26	39	15
2008	828,328	35	27	38	13
2009	976,686	32	32	36	10
2010	1,222,286	32	34	34	9
2011	1,633,347	32	36	32	8
2012	2,050,649	32	36	32	7
Annual growth rate in different periods (%)					
1985–1989	23	3	42	41	3
1990–1994	17	17	13	37	19
1995–1999	13	14	7	23	14
2000–2004	20	26	13	22	25
2005–2012	28	25	32	26	6
1985–2012	20	17	20	29	13

Source: Tabulated by authors based on aggregate data downloaded from the State Intellectual Property Office's (SIPO's) webpage: http://www.sipo.gov.cn/tjxx/.

Notes: The aggregate data do not report the share of applications by firms. Because we did not have access to information about patent applications that were rejected by SIPO, we could not compute the share of applications by firm in Table 2.1 by ourselves, as we do in Table 2.2.

Table 2.2 lists the number of granted patents from 1985 to 2009. The overall trend mirrors that in Table 2.1. During the whole period, the number of approved patents grew at an annual rate of 19 percent. Design patents saw the most phenomenal rate of growth (28 percent per year) among the three types of patents. The share of patents granted to foreign applicants dropped from 34 percent in 1985 to 8 percent in 2009. Firms have become a major body of innovation. The proportion of patents granted to firms tripled from 16 percent in 1985 to 49 percent in 2009. As to invention patents, patents applied for by firms have exceeded half since 2005.

Table 2.3 Number of granted patents (1985–2009)

Year	Total	Invention (%)	Utility model (%)	Design (%)	Foreign (%)	Firm (%)
1985	9,567	48	46	6	34	16
1986	13,329	30	64	6	23	18
1987	19,945	20	74	6	15	19
1988	24,739	18	75	7	13	18
1989	24,804	17	73	10	13	20
1990	30,329	14	75	11	10	23
1991	37,296	12	75	13	7	23
1992	47,662	11	74	15	7	22
1993	51,640	15	70	15	11	22
1994	55,871	21	61	18	18	24

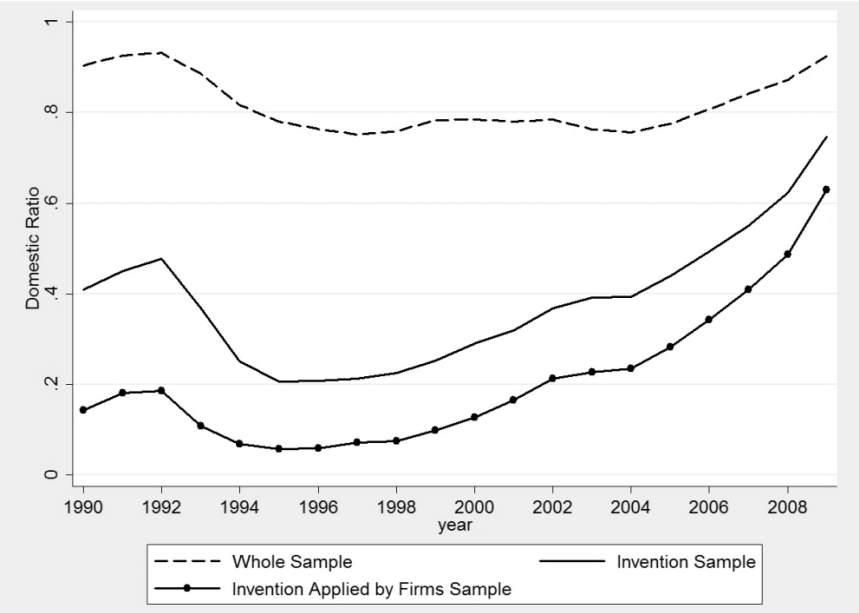
Table 2.4 Continued

Year	Total	Invention (%)	Utility model (%)	Design (%)	Foreign (%)	Firm (%)
1995	62,208	24	53	23	22	28
1996	72,509	25	49	26	24	30
1997	81,886	27	44	29	25	33
1998	91,315	27	42	31	24	34
1999	108,576	25	42	33	22	35
2000	129,030	26	42	32	22	36
2001	153,588	28	40	32	22	35
2002	202,030	29	37	34	21	38
2003	234,839	33	36	31	24	37
2004	267,372	34	33	33	24	37
2005	323,120	33	33	34	22	37
2006	385,688	31	34	36	19	39
2007	451,292	28	33	38	16	41
2008	532,492	26	36	37	13	46
2009	649,263	22	42	37	8	49
Annual growth rate in different periods (%)						
1985–1989	27	–2	42	41	0	42
1990–1994	17	29	11	31	37	15
1995–1999	15	16	9	25	15	22
2000–2004	20	28	14	21	24	20
2005–2009	19	7	26	21	–1	34
1985–2009	19	15	19	28	12	27

Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1, 2014, and applied for as of December 30, 2009.
Note: The last column is determined by the applicant variable on granted patent applications.

Figure 2.1 plots the time trend of the share of patents awarded to domestic applicants in three samples. The top line represents the share of patents granted to domestic applicants in the whole sample. Apparently, the ratio has been rather stable over time. The solid line stands for the share of invention patents awarded to domestic applicants. It first declined from 1990 to the mid-1990s before taking off. By 2009, it reached nearly 80 percent. The bottom line indicates the share of patents granted to domestic firms relative to total firms. It reached the nadir at less than 10 percent in the mid-1990s and spiked to more than 60 percent by 2009. This figure indicates a dramatic improvement in domestic innovation capacity over time.

Figure 2.1 Ratio of patents granted to domestic applicants for three samples over time (1990–2009)

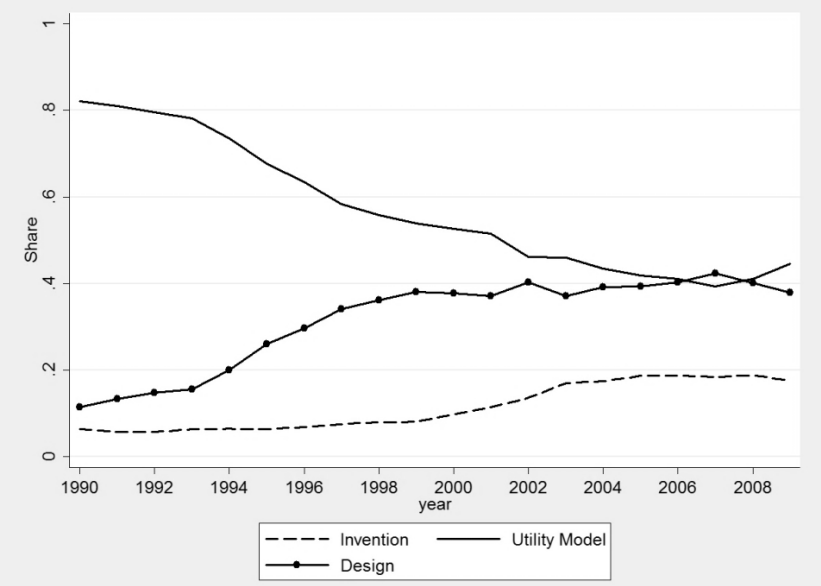


Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1 and applied as of December 30, 2009.

Note: The top curve is the ratio of patents awarded to domestic firms in total patents granted; the middle curve stands for the ratio of patents awarded to domestic applicants in total invention patents; the bottom curve is the ratio of patents granted to domestic firms relative to total approved patents filed by firms.

Figure 2.2 presents the composition of patents granted to domestic applicants. We could clearly see the ratio of utility model patents has declined since 1990, while the share of invention and design patents has increased, indicating a shift in the structure of domestic patents.

Figure 2.2 The composition of patents granted to domestic applicants: Invention, utility model, and design (1990–2009)



Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1 and applied as of December 30, 2009.

SIPO examines all the patent filings and makes grant decisions. Table 2.3 presents SIPO's approval rates according to patent type and origins of application by year.

Table 2.5 Approval rates for invention, utility model, and design patents (1985–2009)

Grant rate	Total	Invention	Utility model	Design
Domestic applicants	0.704	0.398	0.786	0.783
Foreign applicants	0.790	0.782	0.843	0.862
Total	**0.722**	**0.585**	**0.786**	**0.785**

Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1, 2014, and applied for as of December 30, 2009.

A few points about Table 2.3 are worth mentioning. First, foreign applicants enjoy a higher approval rate than do domestic applicants. The approval rate among domestic applicants was 70.4 percent, while it was as high as 79.0 percent for foreign applicants. With respect to invention patents, the gap is more striking. The approval rate for domestic invention applications was only 39.8 percent, about half that for foreign invention applications. Assuming that SIPO follows the same criteria for examining domestic and foreign patent filings, we can infer that the foreign patent filings contain more technological intensity than do domestic filings.

It takes time to process patent applications. We calculated the number of months from patent application to approval by patent type for domestic and foreign applicants. To gauge the time trend, we divided the sample into five periods and computed average time lags in each period. Table 2.4 presents the average processing time. Two salient features stand out. First, the time lags for invention patents, ranging between three and six years, were much longer than those for utility model and design patents, which averaged about one year. Second, it takes longer for foreign applications than domestic applications to be approved. The difference is mainly with invention patents. On average it took more than five years for a foreign applicant to secure a patent, 16 months longer than domestic applicants. Despite the long process, the foreign applicants were subject to a higher approval rate.

Table 2.6 Duration between the time of application and the time of approval (months)

Year	Domestic applicants			Foreign applicants		
	Invention	Utility model	Design	Invention	Utility model	Design
1985–1989	49	12	17	59	12	17
1990–1994	54	11	14	68	12	14
1995–1999	52	16	12	74	18	13
2000–2004	42	13	8	60	16	10
2005–2009	37	12	12	53	16	13
Total	**47**	**13**	**12**	**63**	**15**	**14**

Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1, 2014, and applied for as of December 30, 2009.

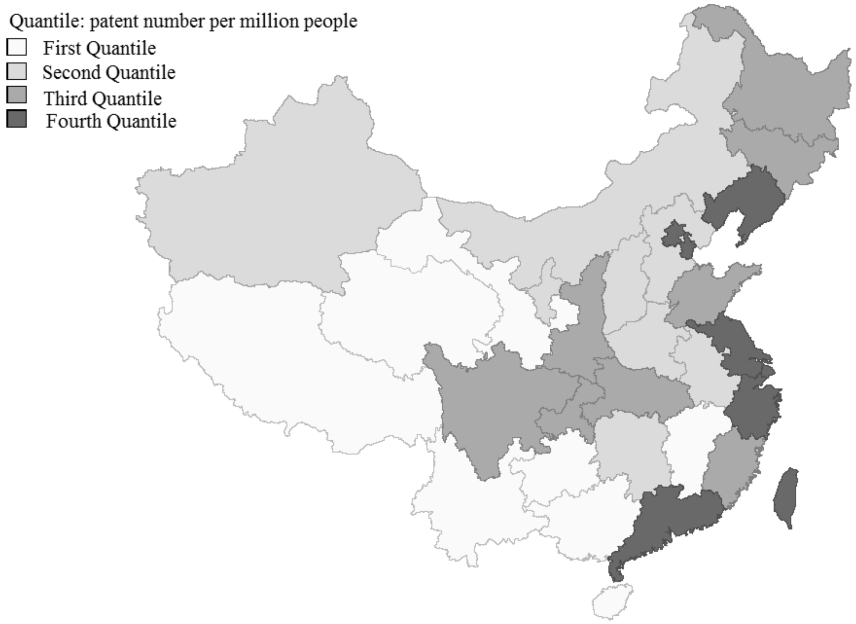
There are large regional variations in terms of innovation. Table 2.5 presents the total number of granted patents by province. Of the top 10 provinces, 8 in the table are coastal provinces, including Guangdong, Zhejiang, and Shanghai. However, the numbers in the table neglect the difference in population size. To remedy this concern, we used population to normalize the number of patents, and the spatial distribution of patents per million people is shown in Figure 2.3. Even on a per capita basis, the coastal region still performed better than inland regions.

Table 2.7 Number of granted patents, by province (1985–2009)

Province	Total	Firms (%)	Invention (%)	Utility model (%)	Design (%)
Guangdong	578,555	45	14	32	54
Zhejiang	401,706	27	9	38	54
Jiangsu	372,255	49	11	38	51
Shanghai	231,676	64	20	39	40
Shandong	226,427	32	10	65	24
Beijing	213,541	40	38	48	14
Taiwan	189,873	55	24	64	13
Liaoning	123,831	22	15	72	13
Sichuan	119,541	29	12	44	45
Fujian	85,868	34	8	41	50
Henan	80,536	33	12	65	23
Hubei	77,949	36	18	62	20
Hunan	76,797	29	15	63	22
Hebei	68,814	27	11	68	21
Tianjin	62,239	47	22	58	20
Heilongjiang	55,146	18	16	71	13
Chongqing	50,853	52	12	47	41
Shanxi	50,412	30	23	61	16
Anhui	47,657	42	14	56	30
Jilin	37,272	21	18	66	16
Yunnan	27,169	28	18	50	32
Shanxi	26,801	27	20	64	16
Guangxi	26,507	30	11	61	27
Jiangxi	26,255	23	12	61	28
Guizhou	18,011	37	18	59	23
Xinjiang	16,774	20	10	70	20
Neimenggu	15,983	26	12	61	26
Gansu	12,843	27	21	64	15
Ningxia	5,985	33	10	51	38
Hainan	5,067	33	17	37	45
Qinghai	2,602	29	16	54	30
Tibet	856	20	13	25	62

Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1, 2014, and applied for as of December 30, 2009.

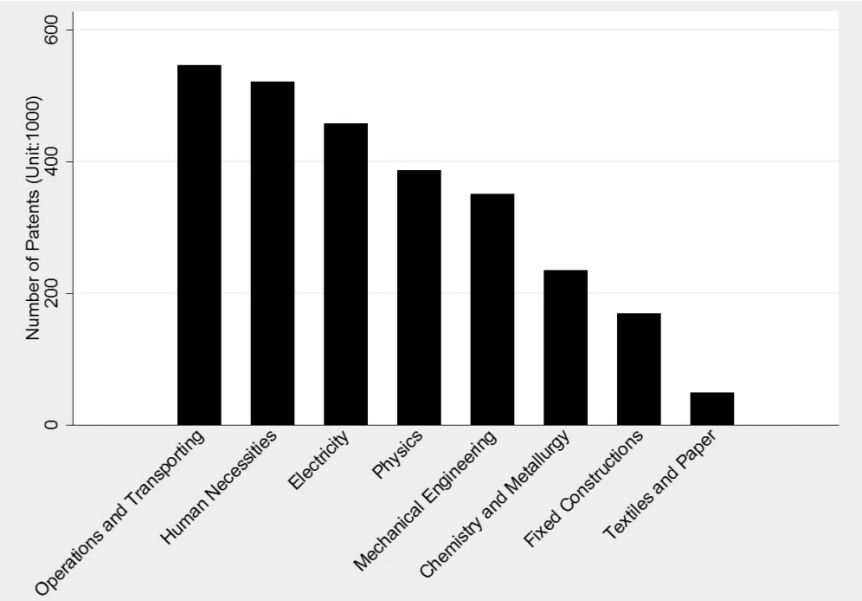
Figure 2.3 Spatial distribution of granted patents, by province



Source: Patent data are calculated based on national database (1985–2009) of patents that were granted as of May 1 and applied as of December 30, 2009. Population data are downloaded from the website of the National Bureau of Statistics.
Note: Hong Kong, Macao, Xisha, Nansha, and Zhongsha Islands are not shown on the map due to lack of data.

Apart from spatial variation, there are large differences across industries in innovation. Figure 2.4 displays the number of patents in each of the eight IPC categories. The operations and transporting industries commanded the largest number of patents, whereas the textile and paper industries ranked at the bottom.

Figure 2.4 Patents granted to domestic applicants, by industry (1985–2009)



Source: Calculated by authors based on national database (1985–2009) of patents that were granted as of May 1 and applied as of December 30, 2009.
Note: The industry is classified according to the International Patent Classification.

3. MATCH PATENT DATABASE WITH FIRM DATABASE

With rising wages, China's comparative advantages as a manufacturing powerhouse are eroding. This is especially true in the labor-intensive light manufacturing industry. Therefore, China has to speed up the process of industrial upgrading and reduce its reliance on labor-intensive industries. To gauge the process of industrial upgrading, we need innovation information at the firm level. To achieve this purpose, we managed to match the patent database with the ASIEC database from 1998 to 2009.

Patents can be applied for by individuals, firms, or other institutions. Those patents applied by firm record only firm names rather than a unique firm identification code used in the ASIEC database. So we had to use firm names as a bridge to match the two databases. Before matching, we first deleted punctuation, which may be due to input errors. Second, we deleted some Chinese words, including "province," "city," "county," "limited liability company," "limited company," "company," and "factory," from the firm names. This step eliminates less important information and increases matching precision. Take "Shenzhen Municipal Huawei Technology Limited Company" as an example. This is the official company name. However, in some entries of the patent database and ASIEC database, the company's name is also listed as "Shenzhen Huawei Technology Limited Company." After deleting the nonessential words, the firm name changes to "Shenzhen Huawei Technology." The identical name now can be easily matched in the two databases. Our method increases the matching rate by about 2 to 3 percent.

In the matched database, 47,298 firms had at least 1 patent. Table 3.1 presents the distribution of the 47,298 firms according to the number of patents owned. Only about 7 percent of firms in the above-scale firm database possessed at least 1 patent. Among those with patents, 27 percent of them owned only 1 patent, and 16 percent 2 patents. In total, nearly two-thirds of firms owned 1 to 5 patents. There are a few outliers—737 firms (1.6 percent of the matched firms or 0.12 percent of the total number of firms included in the above-scale firm database) held more than 100 patents.

Table 3.1 Distribution of granted patents among firms

Number of patents per firm	Number of firms	Percentage
0	635,516	93.0
1 or more	47,298	7.0
Among those with patents		
1	12,653	26.8
2	7,474	15.8
3	4,386	9.3
4	3,248	6.9
5	2,581	5.5
1–5	30,342	64.2
6–10	7,760	16.4
11–20	4,490	9.5
21–30	1,633	3.5
31–100	2,336	4.9
100 or more	737	1.6
Total	**682,814**	**100**

Source: Calculated by authors based on the merged firm patent database (1998–2009) between the national patent database and annual survey of industrial enterprises in China database.

Table 3.2 presents the matching rate by patent type. Since the matched database covers only firms registered in China, foreign firms are naturally excluded. To examine the degree of matching, it is better to use the subsample of domestic firms instead of the total firm sample in the patent database as a benchmark. We define the matching rate as the ratio of matched sample size to total number of patents owned by domestic firms. As shown in Table 3.2, the overall matching rate is nearly 60 percent. There are some slight differences across the three types of patents. The matching rate for invention patents is 55.8 percent, while it is 62.4 percent for design patents. We next provide more evidence to show that the above matching rates are actually high.

Table 3.2 Degree of matching between patent data and annual survey of industrial enterprises in China data

Type of patent	Patents applied for by domestic firms	Share of matched patents in total domestic firm application (%)
Invention	265,713	55.8
Utility model	557,785	57.0
Design	500,077	62.4
Total	**1,323,575**	**58.8**

Source: Calculated by authors based on merged firm patent dataset and national database (1985–2009).
Note: The third column stands for the share of patents granted to the matched firms in total patents applied for (and finally granted) by domestic firms. The sample period is 1998–2009.

Matching errors can stem from several sources. First, our sample includes only SOEs and above-scale manufacturing firms. Many small and medium enterprises (SMEs) and service firms are excluded. Some of them might have applied for patents but are not included in our sample. To check the degree of bias as a result of omitting SMEs, we made use of China Economic Census 2008, which encompasses not only above-scale firms but also SMEs. We create three subsamples out of the census. The first subsample comprises the above-scale manufacturing enterprises in 2008. The second subsample covers below-scale manufacturing firms in 2008. The third subsample includes firms in the service sector. We matched three subsamples in 2008 with our patent database separately and reported the matching rates in Table 3.3. The matching rate for the above-scale firms, SMEs, and service firms are 45.8 percent, 8.8 percent, and 15.8 percent, respectively. Overall, 70.4 percent of the patents applied for by domestic firms can be successfully matched to the firm sample of China Economic Census 2008. Among the three types of patents, the matching rate for invention patents ranks at the top, as high as 79.3 percent, whereas two-thirds of design patents can be matched. Although the number of below-scale firms is larger than that of above-scale firms, they account for a smaller share of domestic firm applications at 8.8 percent. Service firms contribute 15.8 percent of total applications by domestic firms.

Table 3.3 Degree of matching between patent data and China Economic Census 2008

Type of patent	Above-scale firms (%) (1)	Below-scale firms (%) (2)	Service firms (%) (3)	Overall (%) (1) + (2) + (3)
Invention	48.0	5.6	25.7	79.3
Utility model	44.7	9.5	15.3	69.5
Design	45.8	9.8	11.0	66.6
Total	**45.8**	**8.8**	**15.8**	**70.4**

Source: The patent data are from the national database (1985–2009) of patents that were granted as of May 1 and applied for as of December 30, 2009, and the firm data are from China Economic Census 2008.
Note: The above-scale firms in China Economic Census 2008 follow the same definition as the annual survey of industrial enterprises in China database of the National Bureau of Statistics. The last column stands for the share of granted patents in the matched firm sample in total patents awarded to domestic firms.

Second, some firms in the patent database may no longer exist. The matching rate of above-scale firms in 2008 (45.8 percent) is lower than the rate during the longer period from 1998 to 2009 (55.8 percent), as shown in Table 3.2. The result is not surprising. Not all the firms in the above-scale firm database appear in all the years. Some matched firms during the period from 1998 to 2007 may have failed and may have not shown up in the economic census in 2008. Using the ASIEC firm database for the period from 1998 to 2009 can improve the matching rate by 10 percentage points rather than relying on the economic census in 2008. If assuming the same sample attrition rate for the second and third subsamples, we can infer that their matching rates would increase to 11.3 percent and 20.2 percent, respectively, if we could extend the two subsamples to the longer period from 1998 to 2009.[2] The overall matching rate would then improve to 90.3 percent (58.8 percent + 11.3 percent + 20.2 percent). In other words, we failed to match less than 10 percent of the patents filed by domestic above-scale manufacturing firms. Given that firms in other sectors, such as agriculture and construction, are not included in the ASIEC database, it is impossible to match all the firms from the two data sources. In sum, our algorithm has done a great job matching the two databases.

[2] 11.3 = 8.8 * (1 + 28 percent); 20.2 = 15.8 * (1 + 28 percent).

4. SOME INTERESTING PATTERNS DERIVED FROM THE MERGED DATABASE

Having matched the two datasets, now we are in a position to uncover the patterns of patents along several dimensions that are, origins, ownership, and exporting status, degree of clustering, labor intensity, and gender intensity.

Table 4.1 lists the total number of matched patents and the share of different types of firms (private firms, foreign firms, exporting firms, labor-intensive firms, high-clustering industries, and female-intensive firms) over time. However, the statistics in Table 4.1 do not take firm size into account. Firm sizes can differ by employment, capital, and output. Of course, we can normalize the number of patents in different ways. We prefer to normalize the number of patents by million yuan of value added because it better captures the innovation intensity embedded in economic outputs rather than inputs. The results using employment or capital as a denominator reveal similar patterns. So we do not report them here. Figures 4.1 through 4.5 present the normalized number of patents based on value added by exporting status, degree of clustering, capital intensity, and gender intensity, respectively.

Table 4.1 Distribution of granted patents, by firm type and year

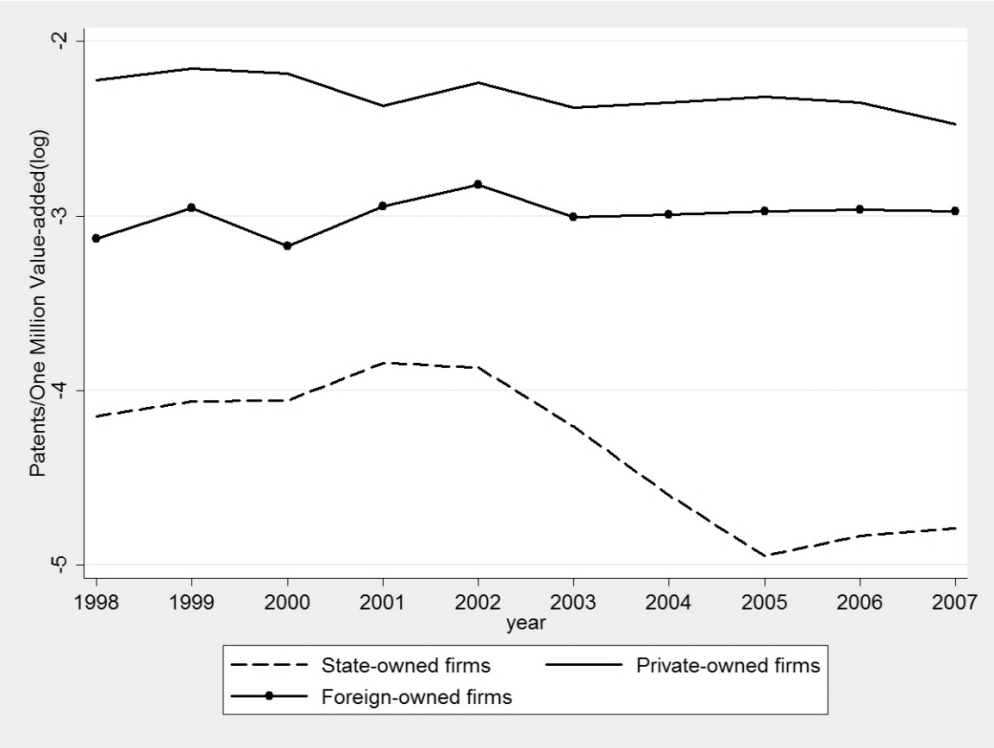
Year	(1) Total	(2) Private firm (%)	(3) Foreign firm (%)	(4) Exporting firm (%)	(5) High clustering (%)	(6) Labor intensive (%)	(7) Female-intensive firm (%)
1998	11,714	49	35	53	68	37	63
1999	16,411	50	37	56	66	36	63
2000	19,809	55	34	54	68	50	61
2001	23,579	53	39	59	71	46	60
2002	34,328	54	38	60	74	53	64
2003	40,161	59	35	63	72	56	60
2004	46,867	58	37	70	72	59	60
2005	59,955	60	35	64	74	80	60
2006	80,314	62	33	66	74	82	60
2007	103,167	62	33	63	69	82	61
2008	134,911	63	32	61	68	82	59
2009	178,475	64	31	56	68	83	56

Source: Calculated by authors based on merged firm patent dataset.

Note: Column 1 is the share of patents owned by firms registered as privately or collectively owned firms. Column 2 is the share of patents owned by firms registered as foreign or by Hong Kong-, Macao-, or Taiwan-owned firms. Column 3 is the share of patents owned by firms whose state ownership is smaller than 50 percent. Column 4 is the share of patents owned by exporting firms. Column 5 is the share of patents owned by firms in high-clustering regions. See Long and Zhang (2011) for the definition of clusters. Column 6 is the share of patents owned by labor-intensive firms. For each year we define a firm as labor intensive if the capital-labor ratio is less than the median value. Column 7 is the share of patents owned by female-intensive firms (see Table A.1 in the appendix for details.

Several interesting patterns emerge. First, we divided firms into three types according to register ownership type—SOEs, foreign firms (including those owned by Hong Kong, Macao, and Taiwan), and privately owned domestic firms. As shown in column 2 of Table 4.1, the share of patents granted to private firms has increased over time, and the share of patents granted to foreign firms has decreased slightly over time as indicated in column 3 of Table 4.1. The result, in number of patents per million yuan of value added, is presented in Figure 4.1. The innovation intensity embedded in state firms decreased during the period, while the innovation intensity of domestic private firms was higher than that of SOEs. Apparently, it is the domestic private firms rather than SOEs that are the engines of innovation in China.

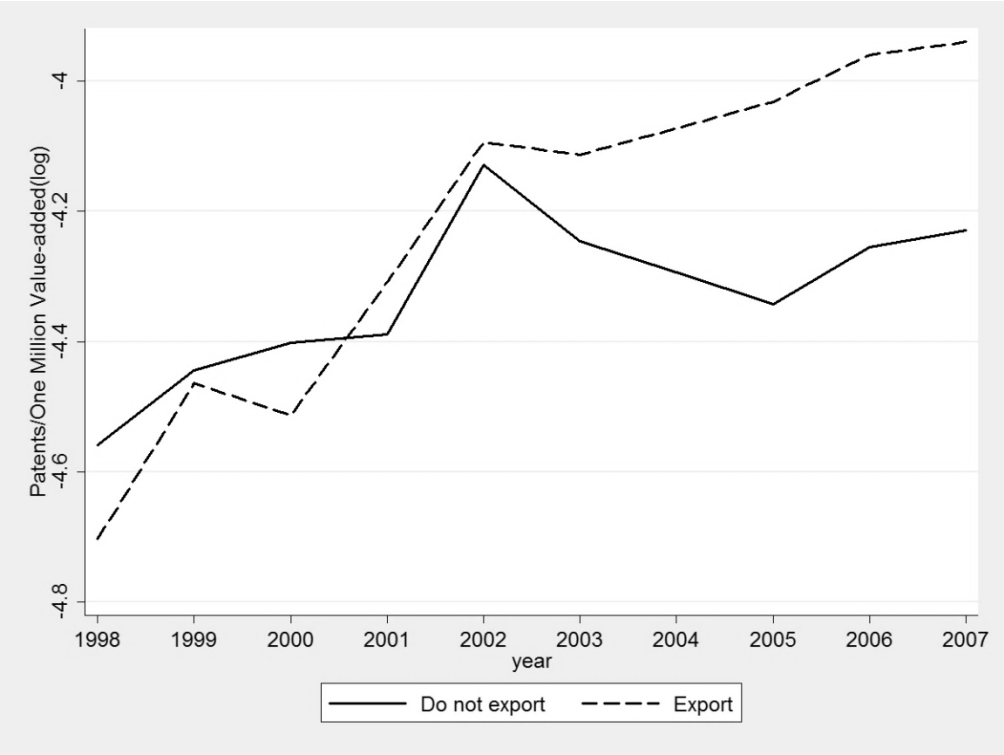
Figure 4.1 Number of patents per million yuan of value-added, by register ownership type



Source: Tabulated by authors based on merged firm patent dataset.

Second, exporting firms are more innovative than non-exporting firms. As shown in column 4 of Table 4.1, exporting firms have consistently contributed to more than half of total firm patents. Trade economists found that exporting firms tend to be more productive than non-exporting firms (Becker and Egger 2013; Bustos 2011; Aw, Roberts, and Xu 2011). One hypothesis is that more productive firms have a higher propensity to export than less productive ones. This is called "selection effect" in the literature. Another hypothesis is that exporting helps improve firms' productivity. It is beyond the scope of this paper to test which hypothesis is more valid. At the aggregate level, we do find that overall exporting firms are more innovative. This has been particularly true since China joined the World Trade Organization (WTO) at the end of 2001. As illustrated in Figure 4.2, the innovation intensity differed little between the exporting and non-exporting firms prior to 2002, but the gap widened significantly after 2002. The divergence may be explained by trade liberalization after China joined WTO (Yu and Ye 2013; Bustos 2011).

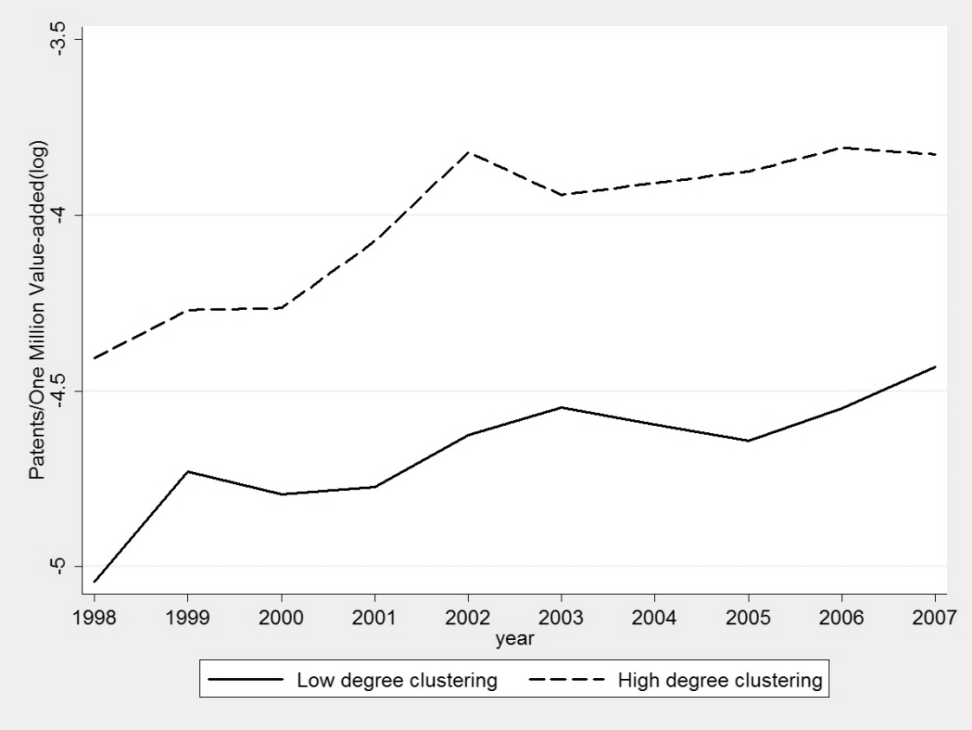
Figure 4.2 Number of patents granted per million yuan of value-added, by firm export status



Source: Tabulated by authors based on merged firm patent dataset.
Note: A firm's exporting status is defined as 1 if it reports export volume and 0 otherwise.

Third, firms in clusters are more innovative. China's industrialization is largely clustered based (Long and Zhang 2011, 2012). The classical literature on clustering has highlighted several key positive externalities of industrial clusters: better access to the market and suppliers, labor pooling, and easy flow of technology know-how (Marshall [1890] 1920). Long and Zhang (2011) found that with less reliance on external financing, more small firms emerge within clusters, leading to higher total factor productivity. We classified regions into high and low clustering regions according to the median value of the cluster measure in Long and Zhang (2011). As shown in column 7 of Table 3.3, the high clustering region explains more than two-thirds of total firm patents. When comparing the number of patents per million yuan of value added, the same pattern remains, as indicated in Figure 4.3. The firms in clusters were consistently more innovative than those outside clusters. The results provide some supportive evidence that clusters foster firm innovations.

Figure 4.3 Number of patents granted per million yuan of value-added, by degree of clustering

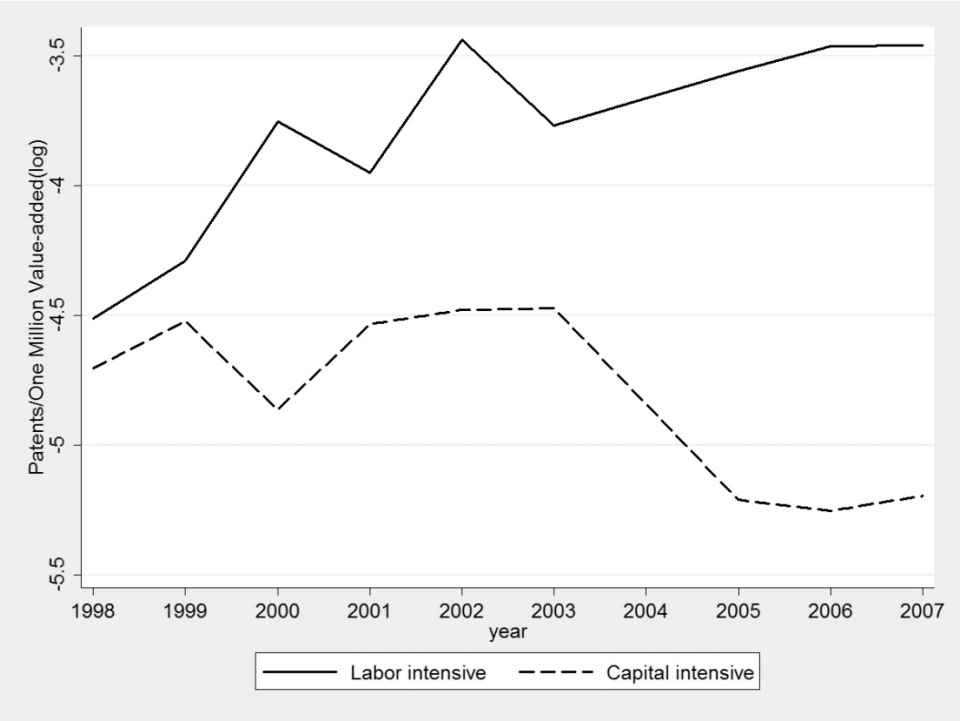


Source: Tabulated by authors based on merged firm patent dataset.
Note: Clustering is defined according to Long and Zhang (2011).

Fourth, labor-intensive firms have become increasingly more innovative.[3] It is a common perception that capital-intensive firms are more innovative than labor-intensive ones. However, we found the opposite. In 1998, patents invented by labor-intensive firms consisted of only 37 percent of total firm patents. But by 2009, 83 percent of firm patents were owned by labor-intensive firms. This probably reflects the increasing wage pressures. As revealed in Figure 4.4, the gap in innovation intensity between labor-intensive and capital-intensive firms China has enlarged significantly since 2003, coincident with the timing when China reached the Lewis turning point (Zhang, Yang, and Wang 2011). Wage escalations since 2003 have likely induced labor-intensive enterprises to invest more in technology and capital to substitute for labor.

[3] We defined a firm as labor intensive if the capital-labor ratio is less than the median value of the whole sample and capital intensive if otherwise.

Figure 4.4 Number of patents granted per million yuan of value-added, by firm capital intensity

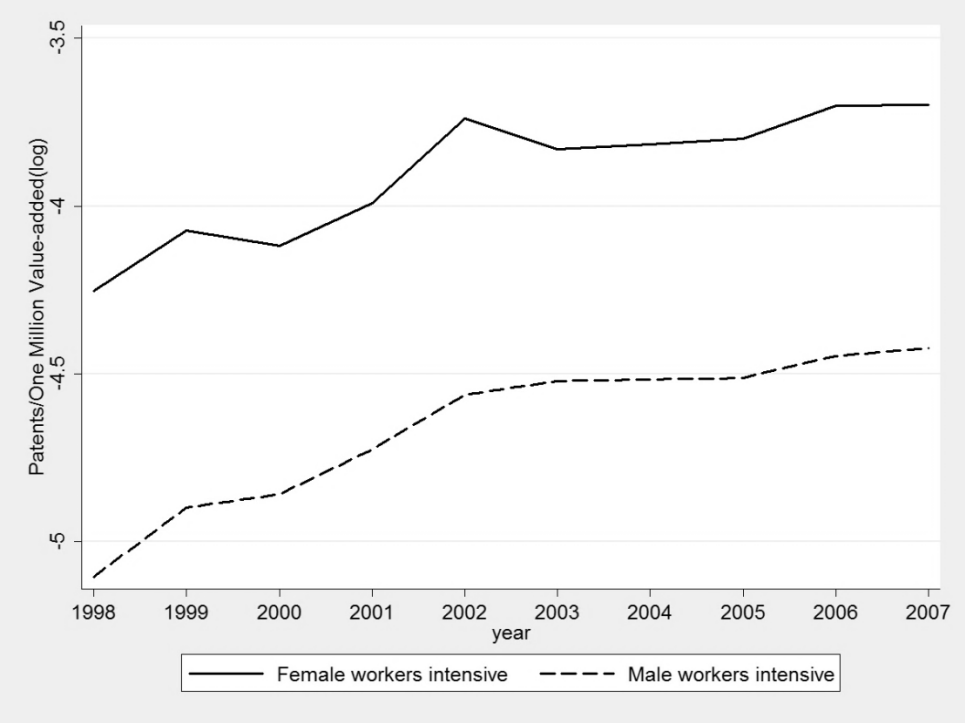


Source: Tabulated by authors based on merged firm patent dataset.
Note: For each year we define a firm as capital intensive if the capital-labor ratio is greater than the median value.

Fifth, industries with a higher proportion of female workers exhibit more innovation. The combination of the introduction of the one-child policy, the availability of ultrasound sex identification technology, and a son-preference culture has resulted in a severely skewed sex ratio in China as high as 120 men per 100 women (Bulte, Heerink, and Zhang 2011; Wei and Zhang 2011). As a result, there is a shortage of women in both marriage and labor markets. Industries that rely mainly on women would have to look for other options to reduce the reliance on increasingly scarcer female workers. Investing in technologies is one option. To test this idea, we grouped firms into two types, female intensive and male intensive. Since the number of employees by gender is available only for 2004, 2005, 2006, and 2007, we had to impute the gender ratio of male to female workers for the earlier years according to the industrial average calculated for the period from 2004 to 2007. We defined an industry as female or male intensive if the average female intensity (the ratio of female to male workers) from 2004 to 2007 is greater than or less than the median value. Table A.1 in the appendix lists the gender intensity for major manufacturing industries. In general, gender intensity changes slowly over time. So our imputation should have minimal impact on the robustness of our results.

Column 7 of Table 4.1 indicates that on average female-intensive industries have secured more patents than have male-intensive industries. With respect to innovation intensity, female-intensive firms consistently perform better their male-intensive counterparts (see Figure 4.5). It seems that sex ratio imbalances matter to firm innovation behavior.

Figure 4.5 Number of patents granted per million yuan of value-added, by industry gender intensity



Source: Tabulated by authors based on merged firm patent dataset.
Note: See Table A.1 in the appendix for the definition of gender intensity.

5. CONCLUSION

China has made huge progress in intellectual property protection. It has become the largest recipient of patent filings in the world since 2011. To unveil the patterns of the dramatic transformation, we have merged the national patent database with the ASIEC database. The merged database enables us to examine the historical patterns of patents across industries and firm types in China.

The explosion in the number of patents in the past three decades means China has greatly improved its innovation capacity. In the 1980s, foreign firms filed most of the invention patents and had a higher approval rate than domestic ones, implying that initially foreign firms had more advanced technologies. However, the domestic firms have caught up over time in both quantity and quality (in terms of invention patents). Firms, in particular domestic ones, have become the key body of innovation in China. Among the domestic firms, it is the private ones that are the engines of innovation. The export-oriented enterprises have witnessed a remarkable spike in innovation since China joined WTO and has had access to a wider market.

The trend of patents also coincides with the timing of labor market and demographic transitions. Since China passed the Lewis turning point, labor has become more expensive relative to capital. As a result, labor-intensive firms have shown a stronger propensity to innovate than capital-intensive ones. Facing the shortage of female workers, the female-intensive industries also exhibit more innovations than male-intensive ones.

Innovation also has something to do with local industry structure. In areas with higher degrees of clustering, firms applied for and secured more patents than those in less clustered areas. Not surprisingly, the coastal provinces, where most of the clusters reside, dominate patent applications.

After all, this paper offers only a descriptive analysis of China's patents. All the findings are suggestive. More solid in-depth analyses are needed to further test the findings. The merged dataset provides us with a vehicle to empirically undertake the tests.

APPENDIX: SUPPLEMENTARY TABLE

Table A.1 Gender intensity, by industry

Code	Industry	Gender intensity
6	Mining and washing of coal	Male intensive
7	Extraction of petroleum and natural gas	Male intensive
8	Mining and processing of ferrous metal ores	Male intensive
9	Mining and processing of nonferrous metal	Male intensive
10	Mining and processing of nonmetal ores	Male intensive
11	Other mining	Male intensive
13	Processing of food	Male intensive
14	Manufacture of foods	Female intensive
15	Manufacture of beverages	Female intensive
16	Manufacture of tobacco	Female intensive
17	Manufacture of textile	Female intensive
18	Manufacture of textile, clothing, and apparel	Female intensive
19	Manufacture of leather, fur, and feather	Female intensive
20	Processing of timber, manufacture of wood, bamboo, rattan, palm, and straw products	Female intensive
21	Manufacture of furniture	Male intensive
22	Manufacture of paper and paper products	Female intensive
23	Printing, reproduction of recording media	Female intensive
24	Manufacture of articles for culture, education, and sport activities	Female intensive
25	Processing of petroleum, coking, processing of nuclear fuel	Male intensive
26	Manufacture of raw chemical materials and chemical products	Male intensive
27	Manufacture of medicines	Female intensive
28	Manufacture of chemical fibers	Female intensive
29	Manufacture of rubber	Female intensive
30	Manufacture of plastics	Female intensive
31	Manufacture of nonmetallic mineral products	Male intensive
32	Smelting and pressing of ferrous metals	Male intensive
33	Smelting and pressing of nonferrous metals	Male intensive
34	Manufacture of metal products	Male intensive
35	Manufacture of general-purpose machinery	Male intensive
36	Manufacture of special-purpose machinery	Male intensive
37	Manufacture of transport equipment	Male intensive
39	Electrical machinery and equipment	Female intensive
40	Manufacture of communication equipment, computers, and other electronic equipment	Female intensive
41	Manufacture of measuring instruments and machinery for cultural activity and office work	Female intensive
42	Manufacture of artwork	Female intensive
43	Recycling and disposal of waste	Male intensive
44	Electric power and heat power	Female intensive
45	Production and supply of gas	Female intensive
46	Production and supply of water	Female intensive

Source: Tabulated by authors based on above-scale firm dataset.

Note: Since we have gender data from only 2004 to 2007, we define an industry as female or male intensive if the gender ratio of workers in the period from 2004 to 2007 is greater than or less than the median value.

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