



**A Tale of Two Cities:
A Comparison of Patent-based
Innovative Performance of
Domestic and Multinational
Companies in China**

*Zheng Liang and
Lan Xue¹*
China Institute
for Science and
Technology Policy
(CISTP)
*School of Public Policy
and Management
(SPPM)*

Abstract

The most remarkable economic phenomenon of the past 30 years may be China's "growth miracle." According to the World Bank (2003), the average growth rates for Chinese gross domestic product (GDP) during the 1980s and the 1990s were 10.1 percent and 11.2 percent, respectively, making China one of the fastest-growing economies in the world. The abandonment of centralized planning and the establishment of market institutions, as well as the market opening to foreign investment, have been credited as keys to the success of this growth. However, China's economic miracle is often attributed to relative abundance of inputs such as labor and natural resources, and not to Chinese innovation. Is this true? What

¹ This article represents solely the views of the authors and not the views of the U.S. International Trade Commission or any of its individual Commissioners. This paper should be cited as the work of the authors only; and not as an official Commission document.

Zheng Liang is the Associate Professor, School of Public Policy and Management (SPPM), Tsinghua University, and Assistant Director, China Institute for Science & Technology Policy at Tsinghua University (CISTP). E-mail: liangzheng@tsinghua.edu.cn. Lan Xue is Professor and Dean, School of Public Policy and Management (SPPM), Tsinghua University, and Director, China Institute for Science & Technology Policy at Tsinghua University (CISTP). E-mail: xuelan@tsinghua.edu.cn. This article is based on a paper presented at the Joint Symposium of U.S.-China Advanced Technology Trade and Industrial Development, October 23–24, Beijing, China.

about the innovative performance of China’s domestic enterprises, in comparison with their competitors from abroad? In this paper, the question is explored using Chinese and U.S. patent data to estimate the innovative performance of firms.

Introduction

The conventional wisdom about intellectual property rights (IPR) is that strong IPR protection generates incentives for investment in research and development (R&D) and, hence, for technological progress in society (Arrow 1962; Nordhaus 1962; Scherer 1972). In addition, IPR protection helps disseminate technical information and reduce social cost (Malchup 1958)—the “information disclosure effect.” All of these benefits make patents not only indicators of innovative performance and capabilities, but also the source of new innovations. At the same time, protecting IPR by assigning a monopolistic right to a piece of knowledge also entails economic costs. A monopoly position in a technology deters other firms from trying themselves to invent “in the neighborhood” (Scotchmer and Green 1990; Green and Scotchmer 1995). As a result, interactions between patent players have multidimensional effects on innovation.

Understanding the role of patents in China is further complicated by the fact that the Chinese economy in the reform era has been far more open than that of many other countries at a comparable stage of development. The patent system in China from the very start faced the double challenge of meeting the demands of multinational companies, which required strong IPR protection, while at the same time satisfying the appeals of domestic companies, which favored an IPR regime conducive to technology transfer and diffusion. This may have led to strategic use of the system, resulting in patenting behavior

The authors would like to express their appreciation to the editors and the two referees, Katherine Linton and Michael J. Ferrantino, for all their constructive comments and valuable advice. The study was partially funded by the China National Soft Science Research Program (No. 2008GXS4K068, No. 2009GXS4K055) and the National Natural Science Foundation of China (No. 70902005). We would also like to acknowledge the support of Mr. Hao Mao, the Intellectual Property Rights Research Center, the State Intellectual Property Office of the People’s Republic of China, and Prof. Sunil Mani, Centre for Development Studies, India, for all their generous help with data collection. The authors, however, are responsible for any errors.

that does not necessarily reflect real innovative performance (Liang and Xue 2010).

In this paper, using empirical evidence from China, the patenting behavior of domestic and multinational firms in China is analyzed in comparison to their innovative performance based on patent data. The paper is organized as follows: part I describes the research methodology; part II briefly describes the evolution of China's patent system; part III investigates the patenting behavior of multinational firms and domestic players at the national level; parts IV and V evaluate the innovative performance of domestic and multinational firms in China at the firm level; part VI compares the patenting behavior of domestic and multinational firms based on the U.S. Patent and Trademark Office (USPTO) data; and part VII notes trends in innovation and patent use among both types of firms while touching briefly on future possibilities.

Methodology

Our analysis is carried out on two levels: at the national level, using patent data on applications, grants, validation, and other parameters, and at the enterprise level. We obtained data about individual and corporate players, both foreign and domestic, as well as different types of patents, including inventions, utility models, and designs, from the Statistical Annals of the State Intellectual Property Office of the People's Republic of China (SIPO) from 1985 to 2007. At the enterprise level, we chose the top 500 firms in China and the top 500 firms globally as the comparative samples.

For our domestic sample, from the list provided by SIPO, we selected 652 enterprises affiliated with China's 500 largest corporations in 2006, each of which had at least one invention patent application before the end of 2004.² We found 16,109 invention patent applications from these firms from April 1, 1985, to December 31, 2004, representing 4.62 percent of the total

² The list has been jointly issued by the Chinese Enterprise Alliance and the Chinese Entrepreneur Association annually since 2004 and ranked by total revenues. The 2006 ranking list (in Chinese) is available at <http://www.cec-ceda.org.cn/buodong/2006china500>. The 652 corporations selected were affiliated with the 500 largest corporations in 2006.

domestic invention patent applications in this period.³ For each application, we obtained the following information: the application date, grant date, prior right,⁴ assignees, inventors and their addresses, the International Patent Classification (IPC) section number, and the IPC class number.⁵ For comparison, we chose the Fortune Global 500 list (2006) as the foreign sample. From the list provided by SIPO of foreign firms that had at least one invention patent application before the end of 2004, we selected 775 affiliated corporations of the above firms. We then searched in SIPO's database and found 108,747 invention patent applications issued by these firms from April 1, 1985, to December 31, 2004, representing 30.47 percent of the total foreign invention patent applications in China in this period. Finally, we used USPTO patent data to compare the patent behavior of domestic and multinational firms operating in China.

³ One firm might have several sub-firms applying for patents in China. Invention data were used instead of patent data because inventions involve more actual technology creation than do the other two forms of patents. Also, this is the only comparable patent field between multinational and domestic firms because most of the patent applications of multinational firms in China are for in-service inventions, and domestic firms are also the only dominant applicants in domestic in-service invention applications. (The in-service invention means the invention made by employee and assigned to the employer.)

⁴ In patent law, a "priority right" (or right of priority) is a time-limited right, triggered by the first filing of an application for a patent. The priority right belongs to the applicant or his successor in title and allows him to then file a subsequent application for the same invention and use data from the date of filing of the first application. When filing the subsequent application, the applicant must "claim the priority" of the first application in order to make use of the right of priority. The period of priority is usually 12 months for patents.

⁵ The Strasbourg Agreement (1971) concerning the IPC provides for a common classification of patents for invention, including published patent applications, utility models, and utility certificates. The IPC is a hierarchical system in which the whole area of technology is divided into a range of sections, classes, subclasses, and groups. This system is indispensable for the retrieval of patent documents when attempting to establish the novelty of an invention or determine the state of the art in a particular area of technology.

Background: The Evolution Of China's Patent System

China's first patent law was enacted in 1984 and came into force in April 1985. In general, the Chinese patent system has more in common with the Japanese system than with that of the United States. For example, the primary purpose of China's patent law is to facilitate the diffusion of new technologies, which is demonstrated by the three kinds of patents allowed (invention, utility model, and design),⁶ their shorter period of validity the adoption of the principle of "first-to-file" instead of "first-to-invent," public disclosure of the invention after 18 months, and mixed requirement of single and multiple privilege claims. Typically, the adoption of "petty patents," such as utility models and designs, are mainly intended to encourage gradual innovation, which is often very important for domestic applicants. This ambition has been achieved in part, according to some empirical studies (Liu et al. 2003; Hu 2006).

China's patent system has evolved in three main stages. The first stage—the founding of China's IPR system—was from 1985 to 1992. Before 1985, China only had a Management System of Science and Technology Achievement, which belonged to the nation and could be freely used. While China's first patent law made it possible for individuals to file patents, it was difficult for inventors to extract monopoly rents except for occasional rewards for inventions (Alford, 1995). At the same time, without permission from the relevant administrative departments in the government, state-owned enterprises (SOEs) could not deal with their patents autonomously (e.g., licensing them out). These limitations dampened the enthusiasm of SOEs, as well as their technical staff, who were key players in industrial R&D. The first patent law also excluded chemical, pharmaceutical, and food or food processing inventions from patent coverage. This was regarded as creating an intentional tilt towards domestic industries, disadvantaging foreign applicants. These issues reflected the evolving balance between stimulating indigenous innovations and sharing in the worldwide knowledge pool by enforcing patent protection.

⁶ In China's patent law, "invention" means any new technical solution relating to a product, a process or improvement therefore. "Utility Model" means any new technical solution relating to the shape, the structure, or their combination, of a product, which is fit for practical use. "Design" means any new design of the shape, the pattern, or the combination, or the combination of the color with shape or pattern, of a product, which creates an aesthetic feeling and is fit for industrial application.

During the second stage, from 1992 to 2000, China's patent system made substantial progress. In the first revision of the patent law in 1992, the duration of patent protection for inventions was extended from 15 to 20 years, and the duration of utility model and design patents was extended from 5 to 10 years. Food, beverages, flavoring, pharmaceutical products, and substances obtained via chemical processes were also covered by patent protection. Another addition to the law was domestic priorities for filing applications. Individuals were allowed to own patents for inventions created during employment if an agreement was made between individuals and employers. All these amendments inspired rapid growth in patent applications.

The third stage is from 2001 to the present. China's patent law experienced a second major revision in 2000. In this revision, state-owned and privately owned enterprises were treated as equals for obtaining patent rights. Other amendments were mainly made to fit World Trade Organization (WTO) requirements, especially those in the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement; one example was the simplification of the examination process. Chinese authorities also increased efforts in IPR protection, with some success. One sign is that damages awarded for patent infringement by the courts have increased tremendously, from hundreds of thousands to tens of millions renminbi (RMB). All of these changes together led to another surge in patent applications.

A Comparison Of Patenting Behaviors Of Domestic And Multinational Companies In China

As discussed above, the evolution of China's patent system echoed the needs of different entities. Once it was founded, it would inevitably mold the behavior of these entities, even though they may have had completely different motivations. The observation of different behavior by multinational and domestic firms under the same patent system is one of the main concerns of this paper. In this section, we use the annual data issued by SIPO to examine

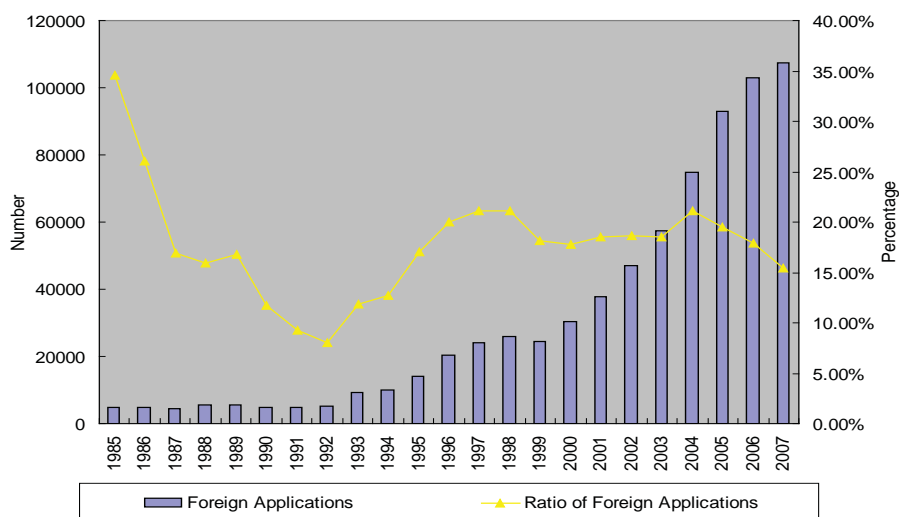
firms' patent applications, grants, and validity in China, in order to discern their innovative performance.⁷

Sources of Patents

As figure 1 reveals, after a lukewarm start, foreign patent applications began to pick up following the first revision of China's patent law in 1992. This can be seen not only in the absolute numbers but also in the figures for foreign applications as a percentage of total applications. As discussed above, this revision brought patent standards in China closer to international standards. Furthermore, with the incentive of favorable policies, there also emerged the first surge of FDI inflows into China since the early 1990s. These two factors together led to a sharp increase of patent applications from foreigners, whose main ambition was to protect their sales and profits in China.

By contrast, the second revision of the patent law in 2000 induced a rapid increase of domestic and foreign applications simultaneously. The growth in domestic patent applications was also strongly stimulated by the central government's initiation of a new patent strategy in 2000, under which patents

Figure 1 Applications for the three kinds of foreign patent applications and their ratio to total applications (1985–2007)



⁷ All the data used in this paper are cited from SIPO Statistical Annals, if not otherwise indicated.

became new evaluation indicators for industrial innovation, especially in public-funded projects. Considerable subsidies and bonuses were awarded to patent applicants by both the central government and local governments.

As shown in figure 2, the ratio of foreign to total invention patent applications reached its peak (62.24 percent) in 1997. After 1997, however, because of the increasing social recognition of patents and strong incentives from the government, domestic applications started growing at a faster rate, surpassing the figure for foreign applications in 2003 even as the latter were still increasing.

More interesting findings are revealed when we observe different kinds of patents as well as patents granted. Even until 2007, more invention patents are granted to foreigners than to locals, although the gap has quickly narrowed in the past five years. From figure 3 we can see distinct fluctuations in grants of invention patents over the past 20 years. Invention patent grants generally decreased for several years after the first revision of the patent law, with grants of patents to foreign applicants decreasing at a faster rate; this resulted in the first decrease in the ratio of foreign to total invention patent grants, from 1990 to 1996. However, as shown in table 1, after 1996 the granting ratio for domestic invention patent filers was distinctly lower than that of foreigners even as the number of domestic applications began to exceed foreign ones, which appears to indicate that the quality of patents filed by domestic entities is comparatively poor.

There are, however, major differences in the behavior of foreign and domestic applicants for utility model and design patents. As table 1 shows, from the patent system's founding in China to the present, domestic applicants have generated more than 99 percent of applications for utility models and more than 93 percent of applications for designs, with similar percentages for the numbers granted. Moreover, these petty patents, which require less progress on technological capabilities and technical breakthroughs and which incentivize incremental innovations and the diffusion of knowledge, are mainly used by domestic players. So, given the analysis above, it can be concluded that the increase in patent applications in China has been mainly due to domestic players' efforts to obtain petty patents which, in turn, is largely the result of the three-tiered system.

Figure 2 Distribution of annual domestic and foreign invention applications (1985–2007)

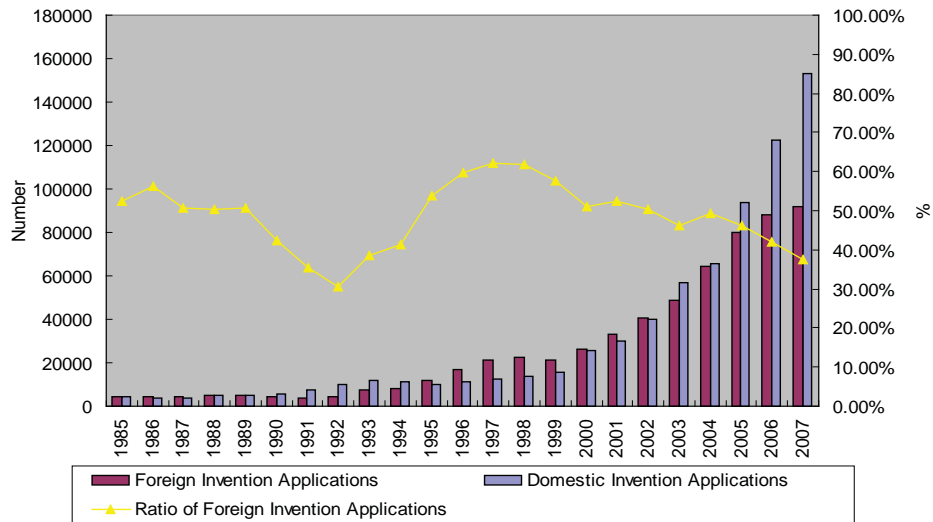


Figure 3 Annual distribution of grants of invention patents to domestic and foreign applicants (1985–2007)

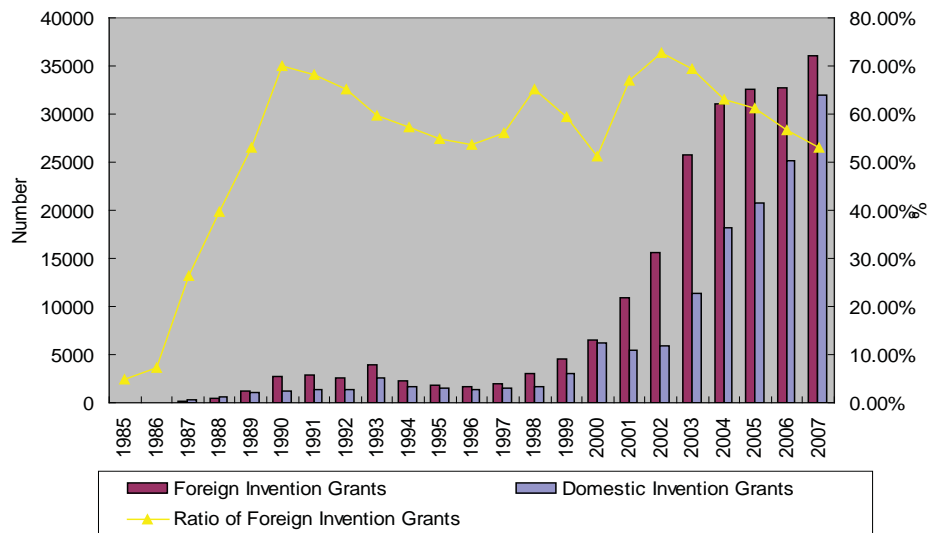


Table 1 Total domestic and foreign applications for the three kinds of patents (April 1985–September 2008)

		Total		Invention		Utility Model		Design	
		Number	Ratio	Number	Ratio	Number	Ratio	Number	Ratio
	Sum	4576636	100.00%	1534934	100.00%	1623279	100.00%	1418423	100.00%
Total	In-service	2310455	50.50%	1184568	77.20%	516158	31.80%	609729	43.00%
	Non-service	2266181	49.50%	350366	22.80%	1107121	68.20%	808694	57.00%
	Sum	3780652	100/82.6	848390	100/55.3	1611467	100/99.3	1320795	100/93.1
Domestic	In-service	1545971	40.90%	522632	61.60%	507198	31.50%	516141	39.10%
	Non-service	2234681	59.10%	325758	38.40%	1104269	68.50%	804654	60.90%
	Sum	795984	100/17.4	686544	100/44.7	11812	100/0.7	97628	100/6.9
Foreign	In-service	764484	96.00%	661936	96.40%	8960	75.90%	93588	95.90%
	Non-service	31500	4.00%	24608	3.60%	2852	24.10%	4040	4.10%

Source: SIPO 2008a.

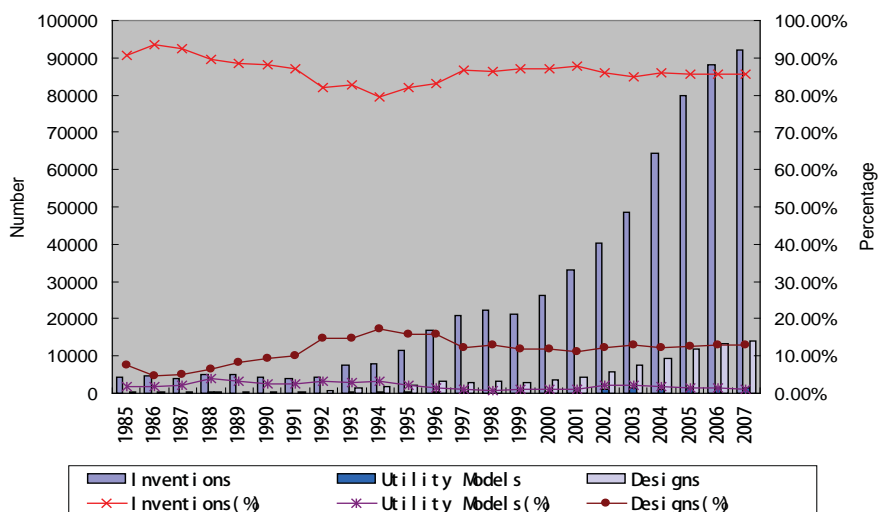
Structure of Patents

Figures 4 and 5 give us a clearer idea of the differing behavior of foreign and domestic patent applicants. As figure 4 shows, the distribution of the three kinds of foreign patent was very stable during 1985–2007; invention patent applications were dominant, which means that foreign players (mainly firms) concentrated mostly on high-quality patents. In most years, invention patent applications accounted for more than 85 percent of the total applications.

Another interesting phenomenon is that although foreign applicants seldom applied for utility model patents (even though these were regarded as “part of inventions” by China’s patent law), they did apply for quite a few design patents. Nonetheless, the ratio of foreign design applications to total applications never exceeded the peak of 17 percent in 1994. Even in 2007, foreigners submitted 1,325 utility patent applications, less than 14 times the number submitted in 1985 (97). But during the same period, foreign invention patent applications in China expanded 20-fold (4,493 to 92,101), and foreign design patent applications expanded nearly 38-fold (371 to 13,993). As some commentators have noted, given that the protection of trademarks in China is weaker than that of patents and given also that they are similar to some extent, some companies may combine trademark registrations with design patent applications (Yang et al. 2004).

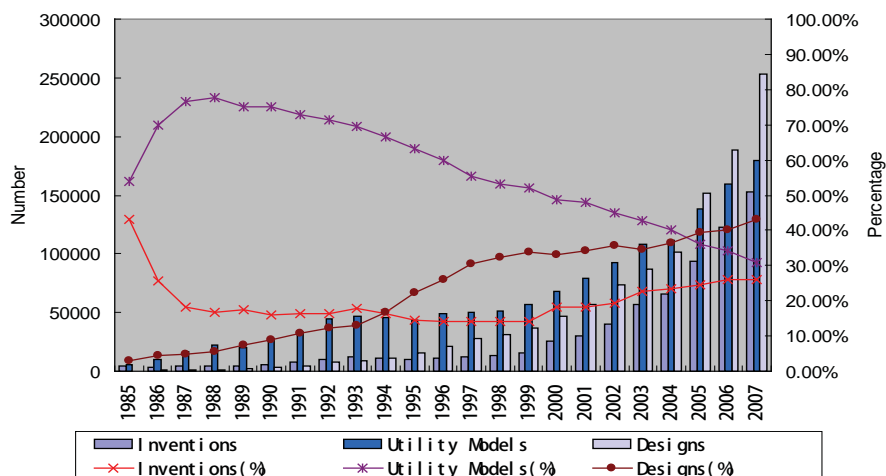
In comparison, as figure 5 shows, the distribution of domestic patent applications is very different from that of foreign applications. Although applications for utility model patents have been dominant in the long term, the ratio of these applications to total applications began to decrease continuously after reaching a peak (77.64 percent) in 1988; this was because of the rapid rise in the number of applications for invention and design patents, especially the latter.

Figure 4 Distribution of annual foreign applications for the three kinds of patents, 1985–2007



As figure 5 depicts, there was a surge of invention patent applications after 2000, but design patent applications expanded even more quickly. As a result, among all patent applications received from domestic applicants in 2007, applications for design patents predominated (43.21 percent), while those for utility model patents ranked second (30.69 percent), followed by those for invention patents (only 26.1 percent). In China, utility models and designs, unlike inventions, need not undergo substantial examination before a patent is granted. Also, because utility model patents have stricter requirements in terms of technological creativity, domestic applicants may have an incentive to select design patents as their first choice of application type, especially small enterprises in traditional areas such as food and beverages.

Figure 5 Distribution of annual domestic applications for the three kinds of patents, 1985–2007



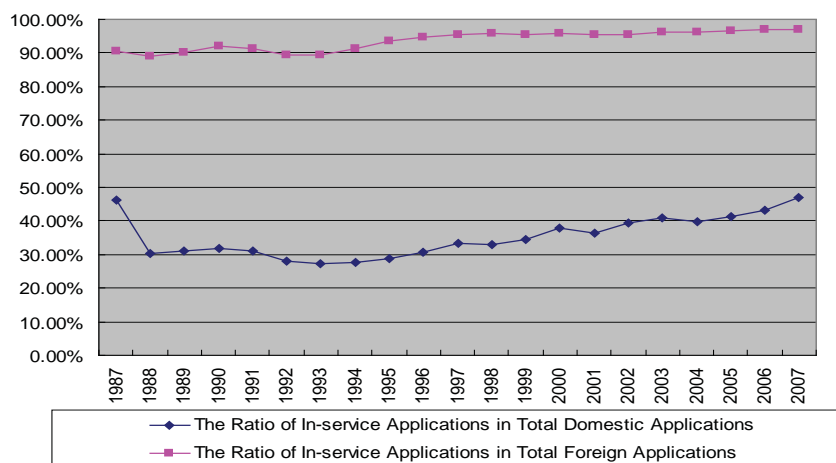
Characteristics of Applicants

More detailed information on the characteristics of foreign and domestic applicants can reveal major differences between them. As figure 6 and table 1 show, in-service applications occupied dominant positions in total applications received from abroad; most of these applications was submitted by multinational companies.⁸ Moreover, the ratio of in-service applications to total foreign applications from 1987 to 2007 was very stable and seldom fell under 90 percent, as figure 5 shows. On the other hand, in-service applications did not exceed 50 percent of annual domestic applications until 2007. What factors account for this difference? If all of the applications are divided into the three kinds of patents, the answer may become clearer. As table 1 shows, there are no distinct differences among in-service application ratios for the three kinds of patents sought by foreigners, except for the relatively low ratios for utility models (75.90 percent). As noted before, the annual number of foreign applications for utility model patents was much lower than that for the other two kinds of patents. It seems that multinational firms seldom apply for utility model patents.

⁸ An in-service application refers to an invention by an employee of a company that is made as part of that employment. Once the application is granted, an in-service patent belongs to the employer. For an application that is not in-service, the individual inventor is the patent holder.

At the same time, domestic applications for the three kinds of patents showed nearly diametrically opposite trends. Among total domestic applications for invention patents, more than 60 percent were in-service. But for utility models, this ratio just exceeds 30 percent, and for designs, the ratio is nearly 40 percent. So it can be concluded that most petty patents in China are sought by Chinese individuals, not by firms and other organizations. The high ratio of individual patent applications in China may be attributed to two factors. First, quite a few petty patents in China are generated by small businesses indeed. But in order to save costs and avoid disputes on property rights, the entrepreneurs themselves may file for many of the patents originated by these firms. Second, because of the ambiguity of the identification of in-service and non-service patents, along with the incomplete IPR protection and incentive systems inside many organizations, some patent applications submitted by corporations are actually filed by individuals.

Figure 6 Comparisons of the ratios of domestic and foreign in-service patent applications



Patent Validity

Once a patent is granted, the patentee must pay annual fees to maintain the validity of the patent. Generally, the patentee will pay this fee only when he or she estimates that the return on this patent will exceed the cost of maintaining it. So we can partially estimate the quality and value of a patent from its validity. As table 2 shows, through 2007, of all the patents granted by SIPO in the past 23 years, only 40 percent were still valid (in force). The validity

ratios for each the three kinds of patents granted to foreigners are higher than those for domestic patents, which implies that foreign patents are more valuable than domestic ones. At the same time, the gap between domestic and foreign invention patents is not very large (66 to 80 percent) compared to the huge gaps for utility models and designs. These gaps suggest that although domestic applications and grants of petty patents grew very quickly in China during 1987–2007 and contributed to the total increase in patents, their quality was still poor compared to the same kind of patents held by foreigners. In fact, many petty patents were given up by the patentees themselves after a short term. From table 2 we can also see that, whether foreign or domestic, the invention patents had the highest validity ratios, which means that invention patents are more valuable than petty patents in China, just as in other countries. According to our interviews with some local firms, the lower validity ratio of patents is also due to the Chinese firms' poor management of IPR, especially the lack of strategic planning and commercializing capabilities in the management and use of patents.

Innovative Performance Of Domestic Firms: Evaluation By Patent Data

As mentioned earlier, China's 500 largest corporations in 2006 were chosen as the population for investigation. During the period 1985–2004, sampled domestic firms applied for a total of 16,109 invention patents in China. Figure 7 presents the annual number of domestic sample firms' invention patent applications. Before 1999, such applications were rare. The first round of patent law amendment boosted domestic firms' invention patent application activities to some degree, but this was not very evident. After 2000, with the second round of patent law revisions, domestic firms' innovation levels increased noticeably, especially in 2002, when invention patent applications increased by 92 percent from the previous year, reaching a total of 3,625.

Table 2 Total numbers of patents applied for, granted, and in force for the three kinds of patents, by domestic and foreign applicants (April 1985 through December 2007)

	Total		Invention		Utility Model		Design	
	Number	%	Number	%	Number	%	Number	%
Total	Application	4028284	1334676	33.10	1471191	36.50	1222417	30.30
	Grant In Force	2089286 850043	364451 271917	17.40 32.00	988284 299242	47.30 35.20	736571 278884	35.30 32.80
Domestic	Grant/ Application In Force/Grant	51.87 40.69		27.31 74.61		67.17 30.28		60.26 37.86
	Application Grant In Force	3314355 1790379 622409	718207 144387 95678	21.70 8.10 15.40	1460557 980029 294463	44.10 54.70 47.30	1135591 665963 232268	34.30 37.20 37.30
Foreign	Grant/ Application In Force/Grant	54.02 34.76		20.10 66.26		67.10 30.05		58.64 34.88
	Application Grant In Force	713929 298907 227634	616469 220064 176239	86.30 73.60 77.40	10634 8235 4779	1.50 2.80 2.10	86826 70608 46616	12.20 23.60 20.50
	Grant/ Application In Force/Grant	41.87 76.16		35.70 80.09		77.44 58.03		81.32 66.02

Source: SIPO 2008b.

Figure 7 Invention patent applications of domestic sample firms (1985–2004)

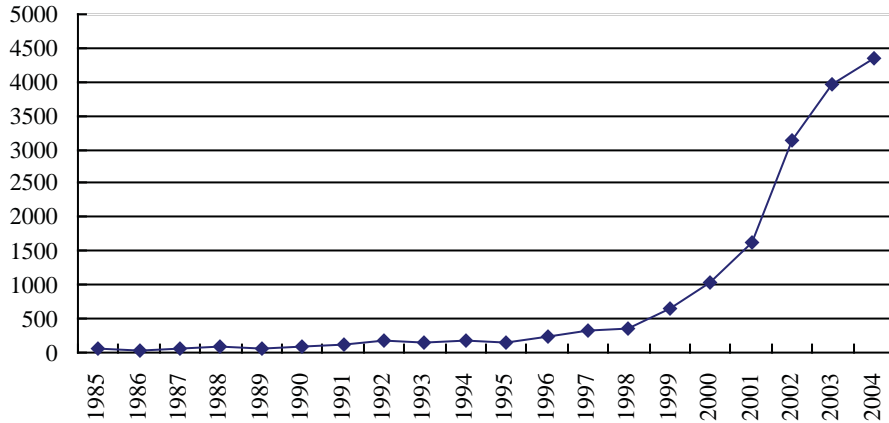


Table 3 presents the provincial distribution of domestic sample firms' invention patent applications. Beijing, Guangdong, and Shanghai are the three provinces with the most such applications, accounting for over four-fifths of the total.

Table 4 lists domestic firms with over 200 invention patent applications during the two decades. Huawei Technology Ltd. applied for 5,365 such patents and ranked first, accounting for as much as 33.3 percent of all invention patent applications filed by sample firms. SINOPEC,⁹ Lenovo Ltd., and ZTE Corporations followed Huawei Technology. These five corporations submitted more than 60 percent of the total invention patent applications filed by all companies in the sample. SINOPEC and Huawei together accounted for 54 percent of applications from the top 500 firms, showing that the top domestic invention patent filers are highly concentrated and that the main players are just several large corporations. However, as stated before, all of the sample companies accounted for only 4.62 percent of the total domestic invention patent applications, which means that more than 95 percent of these applications were submitted by firms outside the top 500. In other words, except for several unique firms, invention patent applications are highly dispersed in China.

⁹ Includes China Petroleum and Chemical Ltd., China Petroleum and Chemical Group, and China Petroleum and Chemical Corporation.

Table 3 Top 10 provinces accounting for domestic sample firms' invention patent applications (1985-2004)

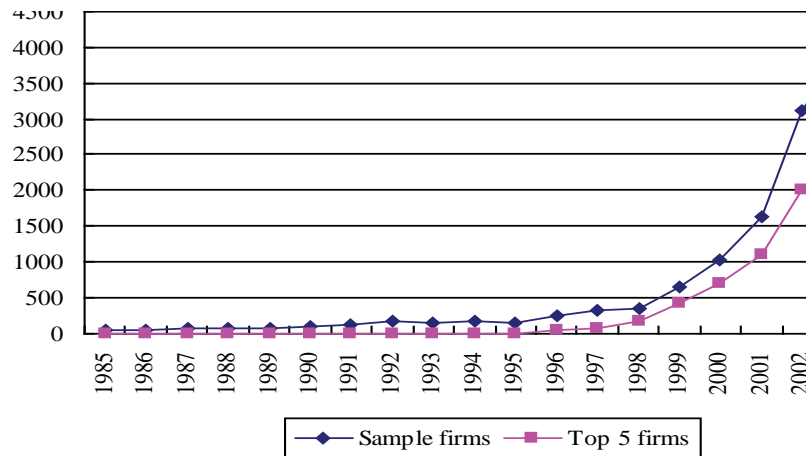
Province	Invention patent applications	Percentage
Beijing	6,586	39.08
Guangdong	6,544	38.83
Shanghai	917	5.44
Shandong	552	3.28
Liaoning	341	2.02
Jiangsu	277	1.64
Hubei	240	1.42
Sichuan	226	1.34
Hunan	166	0.98
Hebei	160	0.95
Total	16,009	94.98

Table 4 Domestic sample firms with over 200 invention patent applications (1985–2004)

Patentee	Industry	Invention application	Percentage
Huawei Technology Ltd.	IT	5,365	33.30
SINOPEC (China Petroleum and Chemical Ltd.)	Chemicals	2,093	12.99
SINOPEC (China Petroleum and Chemical Group)	Chemicals	782	4.85
Lenovo Ltd.	IT	745	4.62
ZTE Corporation	IT	739	4.59
SINOPEC (China Petroleum and Chemical Corporation)	Chemicals	458	2.84
PetroChina Company Limited	Chemicals	346	2.15
Baosteel Ltd.	Steel	325	2.02
Haier Ltd.	Household Durables	256	1.59
Total		11,109	68.95

Figure 8 illustrates invention patent applications of the top five firms listed above, in comparison with the total applications by firms in the sample. Before 1998, these firms submitted very few patent applications. From 1999 to 2002, the share of invention patent applications by the top five firms kept rising, representing 80 percent of overall annual applications by firms in the sample. After 2002, however, the top five firms' rate of applications slowed and they were outpaced by other firms, reflecting a greater recognition of the importance of patents and improved innovation capabilities of other domestic firms.¹⁰ As mentioned above, government incentives since 2000 relating to patent applications (inventions were given more emphasis and stronger incentives) helped spur this increase.

Figure 8 Number of invention patent applications submitted by top five domestic firms and by sample firms (1985–2004)



¹⁰ According to statistics, the average R&D intensity (R&D expenditure to total revenue) of China's large and medium-sized companies increased from 0.46 percent to 0.83 percent during 1995 and 2002.

Table 5 IPC subclass distribution of domestic sample firms' invention patent applications (1985-2004) (those with more than 200 applications)

IPC subclass number	IPC subclass	Invention patent applications	Percentage
H04L	Transmission of digital information, e.g., telegraphic communication	2,675	16.61
H04Q	Selecting	1,595	9.90
G06F	Electric digital data processing	1,120	6.95
C10G	Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g., by destructive hydrogenation, oligomerisation, polymerization	1,067	6.62
B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	826	5.13
H04J	Multiplex communication	726	4.51
H04B	Transmission	598	3.71
C07C	Acyclic or carbocyclic compounds	570	3.54
H04M	Telephonic communication	539	3.35
C08F	Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds	396	2.46
H04N	Pictorial communication, e.g., television	368	2.28
C01B	Non-metallic elements; compounds thereof	274	1.70
G01N	Investigating or analyzing materials by determining their chemical or physical properties	251	1.56
C22C	Alloys	226	1.40
Total		11,231	69.72

Table 6 lists the top five IPC subclass classifications for each of the top five corporations listed in table 4. It can be seen that the top corporations' inventions are highly concentrated in a limited number of IPC subclasses. Generally, the top five categories of IPC subclasses make up 70 to 80 percent

of the overall invention patent applications of a given corporation. Some companies focus on a single very specific area. For example, as table 6 shows, more than 60 percent of Lenovo’s applications fell into one category—G06F. At the same time, some companies, such as Huawei and ZTE, overlap significantly in the areas in which they file patent applications, which may reflect the convergence of their technology and patent strategies. Additionally, in certain categories, some companies have overwhelming advantages. For example, in the H04L category, Huawei submitted nearly 12 times as many applications as its biggest domestic competitor, ZTE, and 16 times as many as another potential competitor, Lenovo. The same relationship can also be found between SINOPEC and PetroChina. In the C10G category, for example, SINOPEC submitted more than 22 times as many applications as PetroChina.

Comparing table 6 with table 5, it can be seen that the IPC subclass distributions of the top firms’ applications are very similar to the distributions of all sample companies. This reflects the fact that among the top companies in China, invention patent applications are highly concentrated among several firms whose patent strategies and filing areas have great influence over the total sampled population. For example, Huawei applied for 2,107 inventions in the H04L subclass, which accounted for nearly 40 percent of its total applications and 78.8 percent of the overall invention patent applications in that subclass submitted by all sample firms; this reflects Huawei’s dominant advantages in this area.

Table 6 IPC subclasses distribution of the top 5 domestic sample firms (1985-2004)

IPC Subclass Number	IPC subclass	Invention Application	Percentage
Huawei			
H04L	Transmission of digital information, e.g., telegraphic communication	2107	39.27
H04Q	Selecting	1134	21.14
H04J	Multiplex communication	496	9.25
G06F	Electric digital data processing	390	7.27
H04B	Transmission	385	7.18
SINOPEC			
C10G	Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g., by destructive hydrogenation, oligomerisation, polymerization	921	27.63

B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	669	20.07
C07C	Acyclic or carbocyclic compounds	421	12.63
C08F	Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds	279	8.37
C01B	Nonmetallic elements; compounds thereof	184	5.52
Lenovo			
G06F	Electric digital data processing	454	60.94
H04L	Transmission of digital information, e.g., telegraphic communication	129	17.32
H04M	Telephonic communication	30	4.03
H04Q	Selecting	26	3.49
H04N	Pictorial communication, e.g., television	19	2.55
ZTE			
H04L	Transmission of digital information, e.g., telegraphic communication	179	24.22
H04Q	Selecting	152	20.57
H04J	Multiplex communication	128	17.32
G06F	Electric digital data processing	63	8.53
H04B	Transmission	63	8.53
PetroChina			
C10G	Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g., by destructive hydrogenation, oligomerisation, polymerization	41	11.85
C08F	Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds	35	10.12
C10M	Lubricating compositions; use of chemical substances either alone or as lubricating ingredients in a lubricating composition	31	8.96
C07C	Acyclic or carbocyclic compounds	29	8.38
B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	24	6.94

Innovative Performance Of Multinational Companies: Evaluation By Patent Data

As mentioned earlier, Fortune Global 500 firms (2006) were used as the population of foreign companies. During 1985 to 2004, foreign sample companies filed a total of 108,747 invention patent applications in China, about 10 times the number filed by domestic sample firms. Figure 9 presents the annual number of foreign sample firms' invention patent applications. As the figure shows, multinational companies' invention patent applications in China peaked twice, with the first peak around 1993 and the second around 2001, similar to the earlier findings in this paper. From 1993 to 1997, foreign applications increased by over 50 percent annually. From 1997 to 2000, they rose more moderately and actually decreased in 1999. During the second upsurge, from 2002 to 2004, a total of 56,432 invention patents were applied for, accounting for over 50 percent of the overall applications for the 1985–2004 period.

Figure 9 Invention Patent Applications of Foreign Sample Firms (1985–2004)

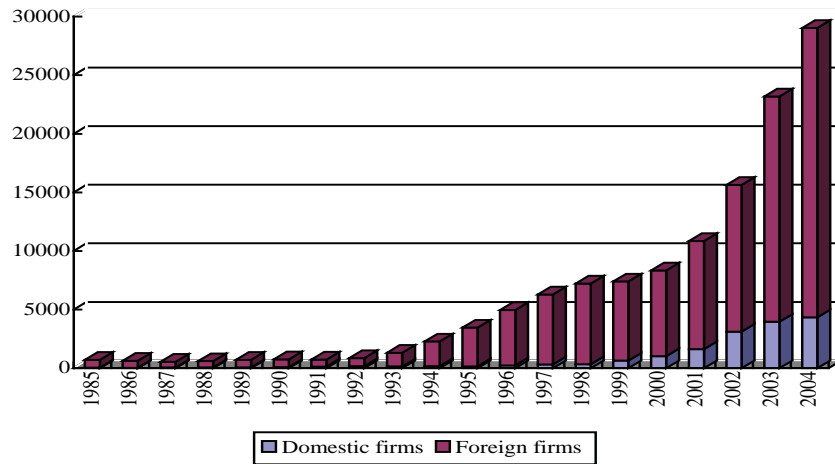


Figure 10 compares the invention patent applications of domestic firms and foreign firms in China from 1985 to 2004. It is clear that before 2000, there was a huge gap between the two groups, with the number of applications from domestic firms less than one-fifteenth those from foreign firms. This mainly reflects the huge gap in innovation capabilities. After 2000, however, applications from domestic firms increased dramatically and reached one-fifth of those from foreign firms, which partly indicates the rapid improvement of domestic innovation capabilities.

With regard to parent country distribution, during 1985–2004 Japanese companies ranked first, with a total of 50,779 filings, or 46.7 percent of total invention patent applications; U.S. companies ranked second with 24,001 filings, or 22.1 percent; Korean companies ranked third with 13,115 filings, or 12.1 percent; and Dutch and German companies ranked fourth and fifth respectively. The companies from these five countries together accounted for over 95 percent of the total foreign invention patent applications.

Figure 10 Invention patent applications of domestic sample firms and foreign sample firms (1985–2004)

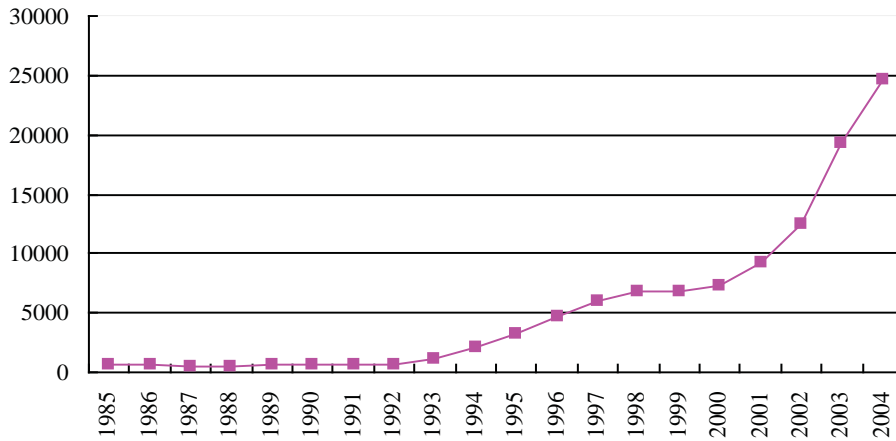
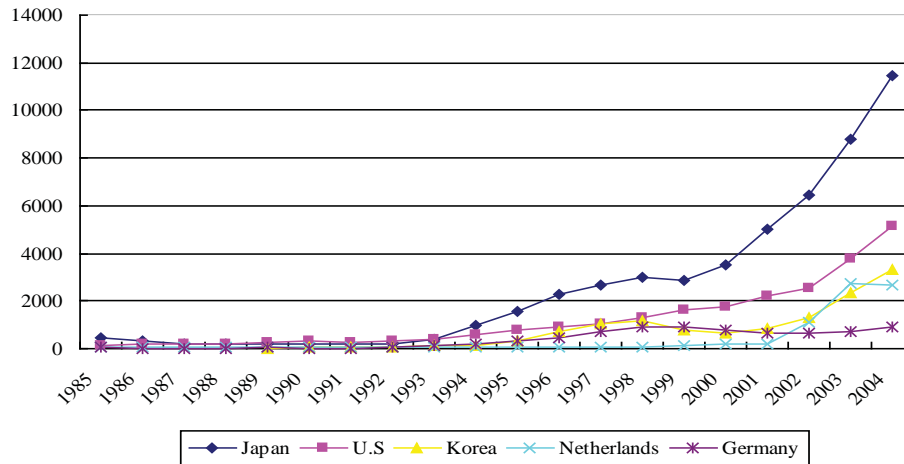


Figure 11 depicts the annual invention patent applications of the above five countries from 1985 to 2004. As the figure shows, there were very few such applications before 1993. Korean firms, which were relatively late entering the Chinese market, applied for their first invention patent in 1989. After 1993, Japanese firms’ annual filing pace accelerated rapidly, whereas that of U.S. firms accelerated rather moderately. Japanese and Korean firms were the largest foreign filers in the USPTO in the 1990s and 2000s. It is likely that the same phenomenon will also occur in China, partly reflecting Japan’s and Korea’s participation in the Chinese market. It is also interesting to note that German firms’ invention patent applications decreased after 1998; the reason needs further investigation.

Table 7 lists foreign firms with over 1,000 invention patent applications from 1985 to 2004. Panasonic (Japan) applied for 12,644 invention patents, ranking first and comprising 11.63 percent of all applications. Samsung ranks second with 9,998 filings, or 9.19 percent. Philips ranks third with 5,586 filings, or 5.14 percent. Out of the top 10 multinational companies, five are from Japan, two from the U.S., and one each from Korea, the Netherlands, and Germany. Generally, applications from Japan are more concentrated among just a few firms, compared to those from the United States. Applications by Samsung, Philips, and Siemens all comprised a large proportion of the total applications from their parent countries.

Figure 11 Annual invention patent applications of the sample companies from top five countries (1985–2004)



Source: Calculated by the authors based on sample companies' data.

Table 8 lists the top 20 PCT¹¹ applicants globally for 2008. All were multinational companies; if we put Tables 7 and 8 together, we find that 11 were also among the top foreign applicants for patents in China. This indicates that the patent strategies of multinational firms in China and globally are not very different. Geographical proximity also apparently plays a role. Some of the companies from Korea and Japan that fall into the second or third rank in terms of applications submitted, such as Samsung, Mitsubishi, Canon, and Sony, play large roles in the Chinese market.

¹¹ Patent Cooperation Treaty (PCT) is an international treaty, administered by the World Intellectual Property Organization, which makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries (that are Contracting States to the PCT) by first filing a single “international” patent application. The authority to grant patents remains entirely with the national or regional patent Offices in what is called the PCT “national phase” or “regional phase.”

Table 7 Foreign firms with over 1,000 invention patent applications in China (1985-2004)

Patentee	Parent country	Invention patent applications	Percentage
Panasonic	Japan	12,644	11.63
Samsung	Korea	9,998	9.19
Philips	Netherlands	5,586	5.14
Siemens	Germany	4,713	4.33
Mitsubishi	Japan	4,454	4.10
IBM	U.S.	4,119	3.79
Canon	Japan	4,117	3.79
Sony Electronics	Japan	3,832	3.52
Sanyo Electronics	Japan	3,122	2.87
Motorola	U.S.	2,769	2.55
Sony	Japan	2,762	2.54
Honda	Japan	2,559	2.35
Intel	U.S.	2,199	2.02
DuPont	U.S.	2,183	2.01
GE	U.S.	2,135	1.96
Fujitsu	Japan	2,060	1.89
P&G	U.S.	1,817	1.67
3M	U.S.	1,557	1.43
Shell	Holland	1,458	1.34
Sharp	Japan	1,424	1.31
Microsoft	U.S.	1,011	0.93
Sumitomo Chemical	Japan	1,009	0.93
Total		77528	71.29

Source: Ibid.

Table 8 Top 20 PCT applicants based on the number of PCT international applications published in 2008

Applicant's Name	Country of Origin	PCT International Applications Published in 2008
HUAWEI TECHNOLOGIES CO., LTD.	China	1,737
PANASONIC CORPORATION	Japan	1,729
KONINKLIJKE PHILIPS ELECTRONICS N.V.	Netherlands	1,551
TOYOTA JIDOSHA KABUSHIKI KAISHA	Japan	1,364
ROBERT BOSCH GMBH	Germany	1,273
SIEMENS AKTIENGESELLSCHAFT	Germany	1,089
NOKIA CORPORATION	Finland	1,005
LG ELECTRONICS INC.	Republic of Korea	992
TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)	Sweden	984
FUJITSU LIMITED	Japan	983
QUALCOMM INCORPORATED	United States of America	907
NEC CORPORATION	Japan	825
SHARP KABUSHIKI KAISHA	Japan	814
MICROSOFT CORPORATION	United States of America	805
MOTOROLA, INC.	United States of America	778
BASF SE	Germany	721
INTERNATIONAL BUSINESS MACHINES CORPORATION	United States of America	664
3M INNOVATIVE PROPERTIES COMPANY	United States of America	663
SAMSUNG ELECTRONICS CO., LTD.	Republic of Korea	639
E.I. DUPONT DE NEMOURS AND COMPANY	United States of America	517

Source: WIPO 2009.

Comparing the distribution of applicants among foreign sample firms with that of domestic sample firms, it is clear that there is much more concentration among the domestic firms. For example, whereas the top five foreign firms accounted for one-third of foreign applications, a single company, Huawei Technology, accounted for one-third of domestic applications. But the concentration is relative; as stated before, the top 500 firms in China accounted for only 4.62 percent of the total domestic invention patent applications. By contrast, the Fortune Global 500 firms accounted for 30.47 percent of total foreign invention patent applications. This indicates that even the top domestic patent filers are still weak in innovation capabilities and in their use of patent strategy, although some unique players, such as Huawei, have emerged.

Table 9 shows the IPC subclass distribution of foreign sample firms' invention patent applications (those with above 2,000 filings). It can be seen that the main

subclasses are digital signal transmission and processing, information storage, and certain semiconductor devices. These five subclasses account for as much as 29.11 percent of foreign sample firms' total invention patent applications. Compared to domestic firms, foreign companies' patent applications are more diversified because many of the firms are conglomerates and operate different businesses simultaneously. It can also be seen from the tables that, except for the chemical sector, the IPC distribution of foreign sample firms is quite similar to that of domestic firms; this means that there is competition between multinational firms and China's leading domestic companies, especially in certain areas such as telecommunication.

Table 9 IPC subclass distribution of foreign sample firms' invention patent applications (1985-2004) (those with over 2,000 applications filed)

IPC subclass number	IPC subclass	Invention patent applications	Percentage
G06F	Electric digital data processing	8,320	7.65
G11B	Information storage based on relative movement between record carrier and transducer	7,064	6.50
H04N	Pictorial communication, e.g., television	5,971	5.49
H01L	Semiconductor devices; electric solid-state devices not otherwise provided for	5,450	5.01
H04L	Transmission of digital information, e.g., telegraphic communication	4,856	4.47
H04Q	Selecting	3,801	3.50
H04B	Transmission	3,204	2.95
H01M	Processes or means, e.g., batteries, for the direct conversion of chemical energy into electrical energy	2,182	2.01
H01J	Electric discharge tubes or discharge lamps	2,137	1.97
G03G	Electrography; electrophotography; magnetography	2,055	1.89
Total		45,040	41.44

Source: Calculated by the authors based on sample companies' data.

The patent data analysis also reveals that during the past 20 years, about 96 percent (or 104,091) of the total 108,747 invention patent applications filed by foreign companies have “priorities” (i.e., they have been applied for before abroad, most likely in their home countries). These filings are mainly based on earlier research and accomplished creations. This confirms Hu’s speculation (2006) that foreign companies bring invention patent applications to SIPO when the market is ready, without necessarily waiting to perfect the technologies. Additional research performed by the authors has also proved this point (Zhu and Liang 2006).

Different Patent Behaviors Of Domestic And Multinational Companies In China: Evaluation By Uspto Patent Data

Some may claim that SIPO patent data are not suitable for comparing the innovative performances of domestic and foreign firms, so we decided to examine USPTO patent data as well for comparison. USPTO patent data are used widely in the innovation research field because of the data’s high standards. The sample we chose includes all of the patents granted by the USPTO to inventors with Chinese addresses from 1969 to 2008, as well as corresponding information, such as grant date and assignees. As table 10 shows, the top holders of USPTO patents in China were individuals, roughly similar to the SIPO patent distribution. There were other kinds of patent players in China besides individuals. For example, among the top five patent holders (not including individuals), three were Taiwanese joint ventures in mainland China.¹² They are focused on ICT product manufacturing (assembling), and their patent behaviors are strictly correlated with their products and main export market. This was the reason why they filed so many patents in the United States. Microsoft ranks second among the top five holders; most of the corresponding patents had been generated by Microsoft’s R&D staff in China but assigned to parent company in US, and were successively implemented into its global product portfolio. The same strategy was also applied by Intel and IBM (Liang and Xue, 2010). Furthermore, although Huawei is the

¹² Hon Hai Precision Industry Co., Ltd., Hong Fu Jin Precision Industry (Shenzhen) Co., Ltd., and Fu Zhun Precision Industrial (Shenzhen) Co., Ltd., are all affiliated with Foxconn Group.

champion in both SIPO and PCT patent (2008) applications in China, it ranks only fifth on this list, behind those joint ventures. This is likely partially due to the non-trade barriers that Huawei has faced in entering the U.S. market.

Besides Chinese foreign-invested companies (including wholly owned firms and joint ventures) and local private enterprises, state owned enterprises such as SINOPEC, are also among the top USPTO patent holders. The reason for this is the strong R&D capabilities they inherited from the planning system age. Top universities, such as Tsinghua, also play very important roles in industrial R&D and patent creation, based on their industrial service tradition and incentives from the government on R&D collaborations with enterprises. Patents, especially foreign patents of SOEs, universities, and public research institutes in China, are occasionally regarded as a symbol of technological strength or reputation rather than a source of commercial benefit. For example, patents were an important indicator in academic promotions in China in recent years, inspiring the surge of applications from universities, both domestically and abroad.

Table 10 Patents granted by the USPTO to Chinese inventors (1969–2008)

First-named assignee	Grants
INDIVIDUALLY OWNED PATENT	1,033
HON HAI PRECISION IND. CO., LTD.	641
MICROSOFT CORPORATION	295
HONG FU JIN PRECISION INDUSTRY (SHENZHEN) CO., LTD.	205
FU ZHUN PRECISION INDUSTRIAL (SHENZHEN) CO., LTD.	109
HUAWEI TECHNOLOGIES CO., LTD.	103
TSINGHUA UNIVERSITY	101
CHINA PETROCHEMICAL DEVELOPMENT CORP.	79
INTEL CORPORATION	74
CHINA PETROLEUM AND CHEMICAL CORPORATION	65
SEMICONDUCTOR MANUFACTURING INTERNATIONAL (SHANGHAI) CORPORATION	62
SAE MAGNETICS (H.K.) LTD.	61
INTERNATIONAL BUSINESS MACHINES CORPORATION	49
SHENZHEN FUTAIHONG PRECISION INDUSTRIAL CO., LTD.	42
WINBOND ELECTRONICS CORP.	37
UNITED MICROELECTRONICS CORPORATION	27
ASIA OPTICAL CO., INC.	24
CHANGCHUN INSTITUTE OF APPLIED CHEMISTRY, CHINESE ACADEMY OF SCIENCES OF CHINA	23

Source: Calculated by author based on the USPTO database.

As the USPTO data discloses, there are different kinds of domestic firms in China; their patent behaviors abroad are diversified and different from those of multinational firms operating in China. This also reflects one face of their different innovative performances. The main holders of patents may not be the most innovative firms.

Conclusions

As the SIPO patent data reflect, the innovative performance of multinational companies during 1985 to 2004 far surpassed that of China's domestic firms, in both quantity and quality. Most foreign patent applications were for inventions and in-service applications, and have higher granting and validity ratios than domestic applications. However, multinational firms' patent applications in China are mainly regarded as competition tools oriented toward market benefits, either actually or potentially. They use China's patent system to provide them with a strategic competitive advantage rather than to gain monopoly rent from their technological advantage. At the same time, however, their patent applications in China not only inspire the "patent competition" in corresponding areas, but also give a chance for domestic firms to imitate and "invent around." Some empirical studies reveal correlations between foreign invention patent applications and domestic utility/design applications, which partly proves this point (Liu et al. 2003; Hu 2006).

Local firms also adapted to China's patent system through gradual innovation, taking advantage of the two kinds of patents for minor innovation. However, most Chinese firms have not been able to become true innovators in their corresponding industries, as evidenced by the lower granting ratio for their invention patent applications, with a few exceptions such as Huawei. Despite a domestic patent surge in recent years, local firms' understanding of patent and patent strategies is still at an early stage. The small quantities and low concentration of leading firms in domestic invention patent applications partially reveals this. In particular, the weak orientation toward innovation and pervasively imitative behaviors among domestic firms may also harm the cultivation of their long-term and core competences.

As the USPTO patent data disclosed, there have been three different pathways to innovation in China. The first is for a firm to orient its innovations toward the lower levels of the international industrial value chain, drawing on China's unchallenged advantages in large-scale and low-cost production (processing/assembling) capabilities and successively growing into a company that can deliver integrated manufacturing services, including product design; a good example of such a company is Foxconn. The second is to compete in an advanced market based on low-cost R&D talent and quick response to customer needs. Examples in the telecommunication sector include Huawei and ZTE, whose innovative capabilities experienced an exceptional boost

due to the severe competition in the global market. The third is to exploit the unique needs of the domestic market while cultivating autonomous R&D capabilities, finally developing new technology, products, or business models that can also compete in the global market. Some SOEs, such as SINOPEC and China Mobile, have this potential but need to overcome the disadvantages on corporate governance so as to fully develop their capabilities.

However, accompanied with the improvement of capabilities, the innovative performance and pathway of different kinds of firms may also converge. Huawei's story is a typical case. Huawei has 83,000 employees, of whom 43 percent are dedicated to R&D. Huawei spends more than 10 percent of its total revenue on R&D every year. Today, Huawei has become one of the leading suppliers of next-generation telecommunications networks and serves 35 of the world's top 50 operators, including Vodafone, British Telecom, Telefonica, France Telecom/Orange, and China Mobile. Huawei has over 1 billion users worldwide, and more than 70 percent of its revenues come from abroad. In fact, it was Cisco's lawsuit against Huawei for patent infringement (settled in 2004 after 20 months) that directly stimulated the formulation of Huawei's IPR Strategy. Huawei founded a pre-research department which includes more than 1,000 people and emphasizes cutting-edge technological research. At the same time, Huawei strengthened patent analysis and concentrated on the breakthrough technologies, such as Wideband Code Division Multiple Access (WCDMA), that would build on Huawei's comparative advantages. It improved collaboration with multinational firms and founded strategic partnerships with most of its industry peers, such as 3Com and Siemens. Huawei made every effort to obtain technologies through licensing and through mergers and acquisitions. It also actively participated in the process of establishing international standards and became a member of 83 standardization organizations. As a result, Huawei filed 6,770 new patents in 2009, bringing its total number of patents filed to 42,543 (Huawei n.d.). It also became the world largest patent applicant under the WIPO PCT, with 1,737 applications published in 2008; Huawei's patenting sustains its worldwide business expansion. Huawei has followed a competitive strategy of not only relying heavily on IPR protection of its core technologies but also using its own technological advantage to integrate global innovation resources. During this process, Huawei developed new collaborative relationships with multinational firms, whose roles also changed towards Huawei: first they acted as "teachers," then as competitors, and finally as collaborators. This has become the typical road for China's domestic leading companies, such as Lenovo, Chery, Geely, and others.

On the other hand, multinational firms, such as Microsoft, IBM, Intel, and Nokia, are searching for new knowledge in China and aim to allocate this knowledge worldwide. Multinational firms' innovation models in China may also converge with those in advanced markets in the future, to some extent. Chinese domestic firms may also integrate their knowledge acquired worldwide and use it to serve domestic market needs.

References

- Alford, W.P. 1995. *To steal a book is an elegant offense: Intellectual property law in Chinese civilization*. Stanford, CA: Stanford University Press.
- Arrow, K.J. 1962. Economic welfare and the allocation of resources for invention. In *The Rate and Direction of Inventive Activity*, edited by R.R. Nelson. New York: Princeton University Press.
- Blind, K., J. Elder, R. Frietsch, and U. Schmoch. 2004. Scope and nature of the patent surge: A view from Germany. In *Patents, Innovation and Economic Performance*. Paris: OECD.
- Bruun, P., and D. Bennett. 2002. Transfer of technology to China: A Scandinavian and European perspective. *European Management Journal* 20 (1): 98–106.
- Chen, X., and C. Sun. 2000. Technology transfer to China: Alliances of Chinese enterprises with western technology exporters. *Technovation* 20:353–62.
- Commission on Intellectual Property Rights. 2002. *Integrating intellectual property rights and development policy*. London, UK: Commission on Intellectual Property Rights.
- Ernst, H. 2001. Patent applications and subsequent changes of performance: Evidence from time-series cross-section analyses on the firm level. *Research Policy* 30:143–57.
- European Union Chamber of Commerce in China. 2005. *European business in China: Position paper 2005*. Beijing.
- Funk, J.L. 1998. Competition between regional standards and the success and failure of firms in the world-wide mobile communication market. *Telecommunications Policy* 22 (4/5): 419–41.
- Green, J., and S. Scotchmer. 1995. On the division of profit in sequential innovation. *RAND Journal of Economics* 26:20–33.
- Greguras, F. 2007. Intellectual property strategy and best practices for R&D services in China. *Computer Law & Security Report* 23:449–52.
- Guvanlı, T., and R. Sanyal. 2003. Perception and management of legal issues in China by US firms. *Journal of Socio-Economics* 32:161–81.
- Hippel, V. 1988. *The sources of innovation*. New York: Oxford University Press.

- Hu, A., 2006. What and why do they patent in China? Workshop on Greater China's Innovative Capacities: Progress and Challenges. Mimeo, Beijing: Tsinghua University.
- Hu, A., and G. Jefferson. 2001. FDI , technology innovation and spillover: evidence from large and medium size Chinese enterprises. Mimeo, Brandeis University, Waltham, MA.
- Huawei Technologies Co., Ltd. Research & development, n.d. http://www.huawei.com/corporate_information/research_development.do.
- Liang, Z., and L. Xue. 2010. The evolution of China's IPR System and its impact on the patenting behaviors and strategies of multinationals in China. *International Journal of Technology Management* 51 (2/3/4): 469–96.
- Liu, Y., M. Xia, and X. Wu. 2003. Measurement research on patents of China's top 500 foreign investment corporations and its influence. *Forecasting* 22 (6), 19–23. (In Chinese.)
- Lu, F., and K. Feng. 2005. *Policy choices on developing China's automobile industry with endogenous IPRs*. Beijing: Peking University Press. (In Chinese.)
- Macdonald, S. 2004. When means become ends: Considering the impact of patent strategy on innovation. *Information Economics and Policy* 16:135–58.
- Machlup, F. 1958. An economic review of the patent system. Study of the Subcommittee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, U.S. Senate. Washington, DC: Government Printing Office.
- Mazzoleni, Nelson R. 1998. The benefits and costs of strong patent protection: A contribution to the current debate. *Research Policy* 27, 273–84.
- Merges, R., and R. Nelson. 1990. On the complex economics of patent scope. *Columbia Law Review* 90 (4), 839–916.
- Nordhaus, W.D. 1962. *Invention, growth, and welfare: A theoretical treatment of technological change*. Cambridge, MA: MIT Press.
- Organisation for Economic Co-Operation and Development (OECD). 2005. Intellectual property rights in China: Governance challenges and prospects. In *Governance in China*, OECD. Paris: OECD, 403–32.
- . 2008. *OECD reviews of innovation policy: China*. Paris: OECD Publications.

- Potter, P.B., and M. Oksenberg. 1999. A patchwork of IPR protections. *China Business Review* 26 (1).
- Scherer, F.M. 1972. Nordhaus's theory of optimal patent life: A geometric reinterpretation. *American Economic Review* 62:422–27.
- Scotchmer, S., and J. Green. 1990. Novelty and disclosure in patent law. *RAND Journal of Economics* 21:131–46.
- Simone, J. 1999. China's IPR enforcement mechanism. *China Business Review* 26 (1).
- State Intellectual Property Office of the People's Republic of China (SIPO). 2008a. The Statistics of Accumulated Patent Applications from Domestic and Abroad, source: <http://www.sipo.gov.cn/sipo2008/ghfzs/zltj/zljb>, visited by October 2008.
- . 2008b. Patent Statistical Annals 2007. Beijing: SIPO Publishing House.
- Sun, Y. 2003. Determinants of foreign patents in China. *World Patent Information* 25:27–37.
- Wang, J., and Z. Liang. 2007. An advocacy coalition approach to global governance on technology standard evolution: The case of WLAN standards. *Proceedings of 2007 International Conference on Public Administration (3rd ICPA)*. Vol. 1: 1115–22.
- World Intellectual Property Organization (WIPO). 2009. PCT, the International Patent System Yearly Review: Development and Performance in 2008, Geneva: WIPO Publication No. 901(E).
- World Bank. 2003. World development report 2003: Sustainable development in a dynamic world, New York: World Bank and Oxford University Press.
- Xue, L., and Z. Liang. 2008. Multinational R&D in China: Myths and realities. In *Greater China's Quest for Innovation*, edited by H. Rowen. Stanford, CA: Walter H. Shorenstein Asia-Pacific Research Center, 103–22.
- Yang, D., M. Sonmez, and D. Bosworth. 2004. Intellectual property abuses: How should multinationals respond? *Long Range Planning* 37 (5): 459–75.
- Zhu, X., and Z. Liang. 2006. Patenting behavior of MNCs in China: An analysis based on panel data. Paper presented at the 15th International Conference on Management of Technology (IAMOT 2006), “East Meets West: Challenges and Opportunities in Era of Globalization,” Beijing, May 22–26, 2006.

Zhou Z., H. Zhong, and J. Li. 2006. Analysis of automobile MNCs' control over China's joint ventures. *China's Foreign Trade* 12:20–22. (In Chinese.)