Propensity to Patent, Competition and China's Foreign Patenting Surge *

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Abstract

What determines the decision of an inventor to seek patent protection in a foreign jurisdiction, particularly one where intellectual property rights protection is weak? This paper focuses on competition as a determinant of the patenting decision in the context of the recent foreign patenting surge in China. Using a database that comprises of all patents granted by China's State Intellectual Property Office and the U.S. Patent and Trademark Office, I examine the industry distribution of Chinese and foreign patents and the potential interaction between them. I find that foreign patenting in China is driven by other foreign inventors' patenting in China as well as by domestic Chinese patenting. Using data on China's bilateral trade with other countries at the industry level, I then relate foreign patenting in China to foreign exports to the Chinese market and Chinese domestic patenting. A foreign country's own export to China has an insignificant effect on the number of its Chinese patents, however, the sum of other foreign countries' competing exports weighted by each of the latter's technology proximity to the foreign country concerned has a positive and robust effect. The estimates imply that competition between foreign imports can account for 36 percent of the annual growth of foreign patenting in China.

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1 Introduction

Whether a firm seeks patent protection for its technology in a foreign jurisdiction is an important question to both business managers and policy makers. While the business managers are primarily concerned with the private appropriation of the returns to the technology, the policy makers face the tradeoff between disclosure and monopoly power that is inherent in the grant of patents. These concerns assume greater complexity when innovation is deployed in places where the traditional appropriation mechanisms are relatively ineffective.

The explosive growth of foreign applications for patents issued by China's State Intellectual Property Office (SIPO) provides a natural setting to investigate the determinants of the propensity to patent in China by foreign inventors. From 1995 to 2004, foreign - primarily OECD and the newly industrialized countries - applications for and grants received of Chinese invention patents had been growing at over 30 percent a year.[1] Of the patents granted by Chinese SIPO to foreign applicants, over ninety percent have claimed foreign priority, which implies that patent applications had earlier been filed for the invention with a foreign jurisdiction. Therefore one can think of a foreign inventor's application and grant of a Chinese patent as an indicator of her propensity to patent in China.

There are four potential explanations of increasing foreign propensity to patent in China: strengthening of patent protection in China over time, expansion of foreign economic activities in China - foreign direct investment(FDI) and trade, imitative and innovative threat from domestic Chinese firms, and competition from

[1]Hu and Jefferson (2008) first identified and investigated the driving forces behind China's patent explosion. They found that a number of economic forces have contributed to the explosive growth of patent applications and grants in China. These include foreign direct investment, pro-patent legislation and ownership reform. The large and medium size Chinese enterprises data they used only covered the patents granted to these Chinese enterprises, which are an important but small portion of all the patents SIPO grants. The enterprise data did not allow them to differentiate between invention and utility model patents either. Utility model patents dominate in numbers, arguably carry much less technological significance than invention patents, and yet receive equal legal protection during their shorter statutory life.

other foreign firms in the Chinese market.

It is hard to assess how the efficacy of IPR enforcement in China has evolved over the years. While reported incidences of IPR violation indicate the severity of the problem, it might also be a result of strengthened enforcement that leads to better detection of violation. Without systematic data on IPR enforcement, I will have little to say about the patent enforcement mechanism in China and will be content with controlling for changes of enforcement effectiveness over time.

As foreign firms expand their engagement with the Chinese economy, whether through FDI or trade, the risk of exposing their intellectual property to potential imitators increases. Deepening and broadening their economic activities in China may also necessitate the introduction of newer and more sophisticated technology over time. Therefore the propensity of foreign firms to patent in China is expected to go up over time. I summarize this as the market covering hypothesis.

A firm's decision of whether to apply for patents in a foreign jurisdiction is also dependent on her competitors' patenting decisions in the same jurisdiction. To the extent that a Chinese patent helps to secure the return to a foreign technology introduced in the Chinese market, such return will depend on whether and what competing foreign or Chinese technologies have been or will be introduced and patented in the same market. If the competing technology is imitation in nature, this would prompt foreign firms to raise their Chinese patenting efforts. When competitors introduce bona fide innovations, foreign firms may or may not seek more Chinese patents in the same market. This is the competitive threat hypothesis.

I use a data set that provides applicant and technology class information of all of the 1.37 million patents that China's SIPO has granted from 1985 to 2004. These patents are then assigned to International Standard Industry Classification (ISIC) manufacturing industries using the OECD Technology Concordance, a variant of the Yale Technology Concordance. I also create a corresponding sample for the U.S. Patent and Trademark Office granted patents. Using these data sets, I investigate the validity of the market covering and competitive threat hypotheses in explaining the increasing foreign propensity to patent in China.

The rest of the paper is organized as follows. Section 2 provides an overview of the patent surge at China's SIPO. It characterizes countries' relative position in the technology space by computing their technology proximity using SIPO patent data. In the following section, I briefly discuss the methodology of mapping patents to industries using the OECD Technology Concordance. Section 4 consists of a general discussion of the propensity of foreign inventors to apply for Chinese patents. In Section 5 I estimate a patenting equation to assess the nature and intensity of the interaction between countries' patenting activities in China. The competing imports measure is used to investigate whether more competition between foreign applicants leads to more patent applications and grants in Section 6. Finally, Section 7 concludes with some observations of policy implications.

2 Patenting in China

China reinstituted its patent law in 1985. The law underwent its first major amendment in 1993, which extended the scope of patent protection to cover pharmaceutical products, food, beverages, flavorings, and substances obtained by means of chemical processes. The duration of invention patent protection was extended from 15 to 20 years, while that of utility model and design patents increased from 5 to 10 years. Protection for manufacturing processes has been extended to products that are directly obtained by the patented process. Also, a patentee was granted the right to prevent any other person from importing the patent related product. The grounds for granting compulsory licenses were restricted. The pre-grant opposition was replaced by a post-grant revocation procedure - as a result, the entire process of patent approval was shortened by an average of six to ten months.

As part of China's commitment to complying with the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the second amendment of China's patent law in 2001 has largely, on paper, brought China's patent system in line with international norm. In accordance with TRIPS requirements, the amendments provide patent holders with the right to obtain a preliminary injunction against the infringing party before filing a lawsuit. The new law also stipulates standards, not previously existing, to compute statutory damages. The amendments have also streamlined the administrative procedures of patent applications and opposition.

Under the "first-to-file" principle, the Chinese SIPO grants three types of patents: invention, utility model and design. To receive an invention patent, which the USPTO labels as utility patent, or a utility model patent, which the USPTO does not grant, an invention has to meet the criteria of usefulness, novelty, and non-obviousness. The requirements for invention and utility model patents are different - while invention patent applications are subject to "substantive examination" which requires the patent examiner to conduct a search of prior art and ensure that the three criteria are met, utility model patent applications do not receive substantive examination and are basically granted on a registration basis. As a result, the application cycle for utility model patents is much shorter than that of invention patents. Nevertheless, the same post-grant reexamination and opposition procedure that applies to invention patents is also applicable to utility model patents. Once granted by SIPO, invention patents receive a statutory life of 20 years from the date of application subject to annual renewal; utility model patents are protected for 10 years.

Utility model patents are sometimes referred to as "petty" patents as they usually represent marginally incremental improvement in technology. They are usually justified on the ground that such innovations can easily be imitated when they are put on the market and that they are useful in protecting the intellectual property rights of small enterprises. The USPTO does not grant utility model patents, although many jurisdictions do grant utility model patents including Japan, Korea, Taiwan, France and Germany.[2]

While China's patent system is clear on paper, the actual enforcement of the patent law, its efficacy in particular, is much less transparent. The U.S. Coordinator for International IPR Enforcement cited a 2005 survey of the US-China Business Council, whose members listed IPR enforcement as their greatest concern (Israel, 2006). Also in 2005, U.S. Customs reported that China was the number one source of counterfeit products. On the other hand, the Chinese central government seems to have taken stpdf to strengthen the enforcement of IP laws. For example, 50 reporting centers for IPR violations were set up through out China in 2006. China's IPR White Paper (State Council, 2005) reported that by the end of 2004, local Chinese patent administration departments across the country had resolved 86.3 percent of the 12,058 cases of patent infringement and dispute they received. There has also been some notable anecdotal evidence. An well publicized recent case of patent litigation involved Pfizer and its Chinese patent on sildenafil citrate, the active ingredient of Viagra. In 2001, 12 Chinese generic drug makers jointly filed an invalidation request against the patent with the Patent Reexamination Board of SIPO. The board sided with the Chinese drug makers three years later. However, after Pfizer's appeal, the Beijing No. 1 Intermediate People's

[2]The following countries grant and protect utility model patents: Australia, Argentina, Armenia, Austria, ARIPO, Belarus, Belgium, Brazil, Bulgaria, China, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Ethiopia, Finland, France, Georgia, Germany, Greece, Guatemala, Hungary, Ireland, Italy, Japan, Kazakhstan, Kenya, Kyrgyzstan, Malaysia, Mexico, Netherlands, OAPI, Peru, Philippines, Poland, Portugal, Republic of Korea, Republic of Moldova, Russian Federation, Slovakia, Spain, Tajikistan, Trinidad & Tobago, Turkey, Ukraine, Uruguay and Uzbekistan. See the WIPO web site at: http://www.wipo.int/sme/en/ip_business/utility_models/where.htm.

Court, which is designated to hear patent cases, in a 2006 ruling, overturned the Patent Reexamination Board's decision and upheld Pfizer's Chinese patent. My own interviews with scholars and executives in China suggests that China is more effective in enforcing patent rights than copyrights. But without systematic data, one cannot substantiate such conjecture or perception or differentiate between the consequences of more rampant violation of IPR or more stringent enforcement of the IP laws.

2.1 Top patenting countries

The economies that have been granted the most patents by SIPO and USPTO are listed in Table 1 with their patent grants in 2004 and growth rates of their grants from 1995 to 2004. The same group of economies make it to both lists. In both China and the U.S., Japan, Germany, Korea and Taiwan have been granted more patents than other foreign countries.

Although the number of invention patents granted to Chinese applicants has been growing at an annual rate of almost 26 percent, U.S., Japan, Germany, Taiwan and Korea have been taking out Chinese invention patents at even faster rates. Korea, for example, has seen its number of SIPO invention patents growing by 58.2 percent a year.

Table 1 also shows that the utility model patents are dominated by Chinese and Taiwanese applicants, who together are responsible for over 98 percent of the total. But their numbers have not been growing nearly as fast as invention patents, suggesting rapid improvement in the average quality of SIPO patents.

The growth rates of the USPTO patents have been quite modest compared to those of SIPO patents. The world's three top inventors, U.S., Japan, and Germany, have had their USPTO patents growing at around 5 percent a year from 1995 to 2004. Patents granted to Korea, Taiwan, and particularly China, on the other hand, have been growing at between three to four times the world average rate of 5.4 percent. The much faster rate of foreign patenting in China implies that the rapid growth of the SIPO patents granted to foreign applicants is unlikely to have been driven by more and faster knowledge production in those foreign countries. It has to be that these foreign countries are patenting in China a larger proportion of their exiting inventions.

Table 1: Patenting in China and the U.S.

	China SIPO				U.S. PTO	
	Invention		Utility model		Utility	
	Growth rates 1995-2004	Count 2004	Growth rates 1995-2004	Count 2004	Growth rates 1995-2004	Count 2004
China	25.6%	15,733	9.0%	60,561	20.8%	404
USA	28.2%	6,572	20.8%	218	4.6%	84,271
Japan	36.6%	12,439	12.4%	217	5.4%	35,350
Germany	34.9%	3,043	15.4%	16	5.5%	10,779
Taiwan	39.9%	1,773	9.9%	7,424	14.4%	5,938
Korea	58.2%	2,267	3.3%	70	14.9%	4,428
All patents	30.1%	49,054	9.1%	68,889	5.4%	164,293

Source: author's calculation using SIPO and USPTO data.

2.2 Countries in technology space

A country's R&D outlay is distributed over a spectrum of technological fields and the distribution is shaped by the technology opportunity in these fields. Abundance of technology opportunity is expected to lead to more R&D effort, which in turn leads to more patents subject to the propensity to patent in the technology field. Countries that research and develop in similar technological fields are therefore likely to see their patent portfolios highly correlated. To investigate the simultaneous rapid growth in SIPO patents granted to foreign entities, I first locate the relative position of countries in the technology space.

When a patent is granted, SIPO patent examiner assigns it a primary technology class and one or more secondary technology classes using the International

Patent Classification (IPC) system that all national patent offices use. The IPC is a hierarchical system in which the whole area of technology is divided into eight primary sections, each of which is in turn subdivided into patent classes. Each patent class consists of a number of subclasses. At the lowest level of the hierarchy are technology groups.[3] Therefore IPC becomes a natural system of coordinates to position countries in technology space.

Following Jaffe (1986) I use un-centered correlation between the technology class distributions of the patents of two countries to measure how close they are in technology space.[4] The technology space is spanned by the 164 IPC patent classes. The innovation activity of each economy is then projected to this technology space represented by a 164-element vector with each element occupied by the share of SIPO patents the economy receives in that year in the patent class concerned. Therefore the technology proximity between two economies, i and j, in year t, is defined as:

$$TP_{ijt} = \frac{V_{it}'V_{jt}}{\sqrt{V_{it}'V_{it}}\sqrt{V_{jt}'V_{jt}}} \tag{1}$$

where V_{it} is a 164-element vector of patent class shares of country i's SIPO patents granted in year t. TP is bounded between 0 and 1 and increasing in the similarity between two countries' patent portfolios.

I calculate pair-wise technology proximity between countries using SIPO data and report the results in Table 2. The top panel of Table 2 is based on patents granted to China, Germany, Japan, Korea, Taiwan and USA from 1995 to 1997.

[3]The eight primary sections are coded A to H. For example, Section C is titled "Chemistry; Metallurgy". "Fertilisers; Manufacture thereof" is a class under Section C, coded "C05". Under C05 there are several subclasses, one of which is "C05C", defined as "Nitrogenous fertilisers". Going one level down, one group under subclass C05C is "Ammonium nitrate fertilisers" with the code of "C05C 1/00". For detailed description of IPC, see WIPO's website at http://www.wipo.int/classifications/en/.

[4]Jaffe (1986) used un-centered correlations as weights to construct a measure of knowledge pool that he found to be highly correlated with firm performance.

Table 2: Technology proximity

	$China_U$	$China_I$	Germany	Japan	Korea	Taiwan	USA
			1995-1997				
$China_I$		1.00	0.59	0.63	0.33	0.46	0.62
Germany	0.34	0.59	1.00	0.87	0.32	0.51	0.85
Japan	0.81	0.63	0.87	1.00	0.48	0.58	0.85
Korea	0.84	0.33	0.32	0.48	1.00	0.42	0.46
Taiwan	0.86	0.46	0.51	0.58	0.42	1.00	0.43
USA	0.57	0.62	0.85	0.85	0.46	0.43	1.00
			2002-2004				
$China_I$		1.00	0.72	0.54	0.40	0.39	0.79
Germany	0.59	0.72	1.00	0.77	0.62	0.51	0.89
Japan	0.75	0.54	0.77	1.00	0.89	0.76	0.86
Korea	0.87	0.40	0.62	0.89	1.00	0.61	0.78
Taiwan	0.75	0.39	0.51	0.76	0.61	1.00	0.70
USA	0.49	0.79	0.89	0.86	0.78	0.70	1.00

Source: author's calculation using SIPO data.

The bottom panel uses the last three years of data. For China, I use both the utility model patents ($China_U$) and the invention patents ($China_I$) to compute the technology proximity with others; only the invention patents are used for the other countries.

Using utility model patents as an indicator for imitation and invention patents to represent invention, Table 2 shows that China's imitative effort aligns closely with the inventions of Japan, Korea, and Taiwan, whereas China's inventions mostly track those of the technologies that Germany, Japan, and the U.S. patent in China. Although the technology proximity measure does not tell us anything about causality, there is a substantial degree of overlap between what Chinese innovators imitate and the areas that Japan, Korea, and Taiwan patent in China. In contrast, the distribution of Chinese inventions is highly correlated with the patenting choices made by Germany, Japan, and the U.S..

Overtime, Table 2 reveals that the correlation between the patent class distributions of China and Germany and the U.S. has increased. From the mid 1990s to

2004, technology proximity between China and Germany measured by invention patents increased from 0.59 to 0.72; it increased from 0.62 to 0.79 for China and the U.S.. On the other hand, China's imitation effort moves closer to Germany's invention patenting over the same time period, from 0.34 to 0.59.

Among foreign patent applicants, Korea and Taiwan have both aligned their patent portfolio much more closely with the others and with each other. For instance, in the mid 1990s, the degree of overlap between the portfolios of Korea and Japan was 0.48; towards the end of the sample period, it increased to 0.89. The proximity between Korea and the U.S. has increased from 0.46 to 0.78. The proximity between Germany, Japan, and the U.S. has been high from the beginning but has been stable or even slightly declined over time.

The technology proximity results reveal several interesting patterns of the countries' patent portfolio and the underlying innovation effort. China's imitation seems to focus on areas where Japan, Korea and Taiwan are actively taking out SIPO patents; the high technology proximity between Germany, Japan, and the U.S. shows that the patenting strategies of these world leading innovators are highly correlated; and finally, Korea and Taiwan have been increasingly patenting in areas that were previously dominated by Germany, Japan, and the U.S..

3 Matching patents to industry

A challenge, at least to economists, of using patent data compiled by patent offices to study technological innovation is that they do not tell us which industries the patent applicants come from. Since most economic activities are reported at the industry level, it becomes difficult to analyze patent data in a context of economic agents making decisions of resource allocation. Economists have been trying to overcome this deficiency of patent data since the early efforts of Schmookler (1966) and Scherer (1965a,b).[5] Schmookler (1966) focused on patents related to capital goods invention and aggregated patents from a number of patent subclasses that he determined, by examining the definition of those subclasses and sampling patents within them, to be relevant to a certain industry into a total number of capital goods patents for that industry. The approach of Scherer (1965a,b) was to go to the firm level and aggregate firm patent totals into an industry total for the industry the firms belong to. Both approaches have their limitations in that only a small portion of the vast universe of patent data has been used.[6]

There has been no effort to match Chinese SIPO data to firm or industry level economic variables. The data Hu and Jefferson (2008) used, perhaps the best available, contains a firm-level patent count, which does not differentiate between invention and utility model patents. The patent count is for the large and medium size Chinese firms in the database, which account for 8.7 percent of all patent applications at SIPO in 2001.

3.1 The OECD Technology Concordance

Another approach of making patent data more economically meaningful was undertaken by a group of economists then at Yale University (Evenson and Johnson, 1997; Kortum and Putnam, 1997). They constructed the Yale Technology Concordance taking advantage of the practice of the Canadian Patent Office who assigned, in addition to IPC patent classes, an industry of manufacture (IOM) and a sector of use (SOU) for each of the over 300,000 patents it granted between 1972 and 1995. This patent database provided the natural input to construct a concordance be-

[5]See Griliches (1990) for an early survey and discussion of the data and conceptual issues involved in studying patent statistics

[6]In constructing the NBER patent and patent citations database, Hall et al. (2001) undertook the task of matching the name of a patent assignee to the name of a public listed company so that patent data can be matched with company balance sheet and income statement data. This is a big step forward, but still only publicly listed companies are matched. For an update of the status of this ongoing effort, see Bronwyn Hall's web site at: http://elsa.berkeley.edu/ bhhall/

tween patent classes and industry of manufacture and sector of use of the patents. Assuming that such concordance remains stable over time and across countries, one can use it to study patents granted by any national patent office that assigns IPC classes to the patents it grants.

The original industry assignments that the Canadian Patent Office used and that the Yale Technology Concordance adopted were based on the Canadian standards for industry classification (SIC), which is different from the International Standard Industrial Classification (ISIC) system that is internationally used to define economic sectors. Johnson (2002) added another layer of translation from the SIC to ISIC to construct the OECD Technology Concordance (OTC).

I aggregate SIPO patent data to three-digit ISIC industries using the OTC, which assigns to each IPC patent class a probability that patents from this IPC class belong to a three-digit ISIC industry of manufacture and a different probability that these patents belong to a sector of use, also at the three-digit ISIC level. With this matrix of probabilities, I can then assign most patents - the OTC does not cover all IPC classes - to three-digit ISIC industries. I apply the OTC to both SIPO and USPTO data and will use industry of manufacture to classify patents.[7]

3.2 Top patenting industries

I will concentrate on patents from the manufacturing industries, since most R&D is undertaken in and most patents are taken out by the manufacturing industries. Figures 1 and 2 provide histograms of manufacturing industry distribution of patents.

Figure 1 contrasts industry distributions of SIPO invention patents and USPTO patents. The two distributions look broadly similar. For both SIPO and USPTO, the largest share of patents go to the machinery industry (ISIC 29). For SIPO, the

[7]The USPTO started IPC patent class assignment in 1975, although the USPTO patent data goes back to 1963.

Figure 1: Industry distribution of patents: invention

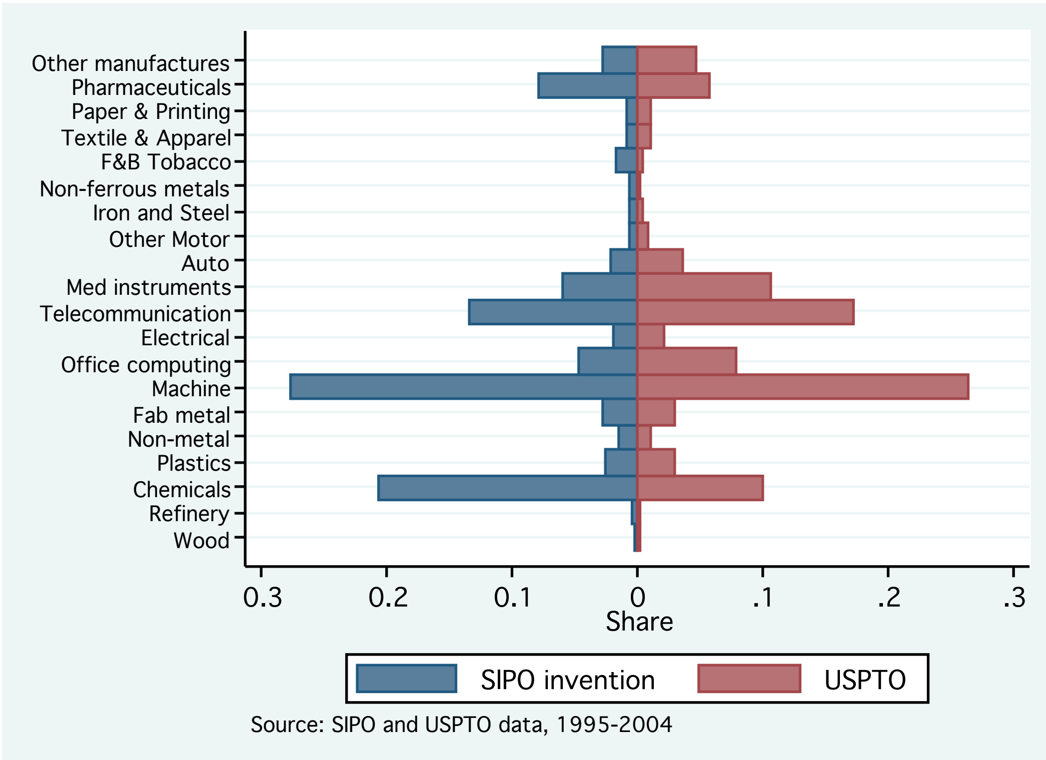


Figure 2: Industry distribution of patents: utility model

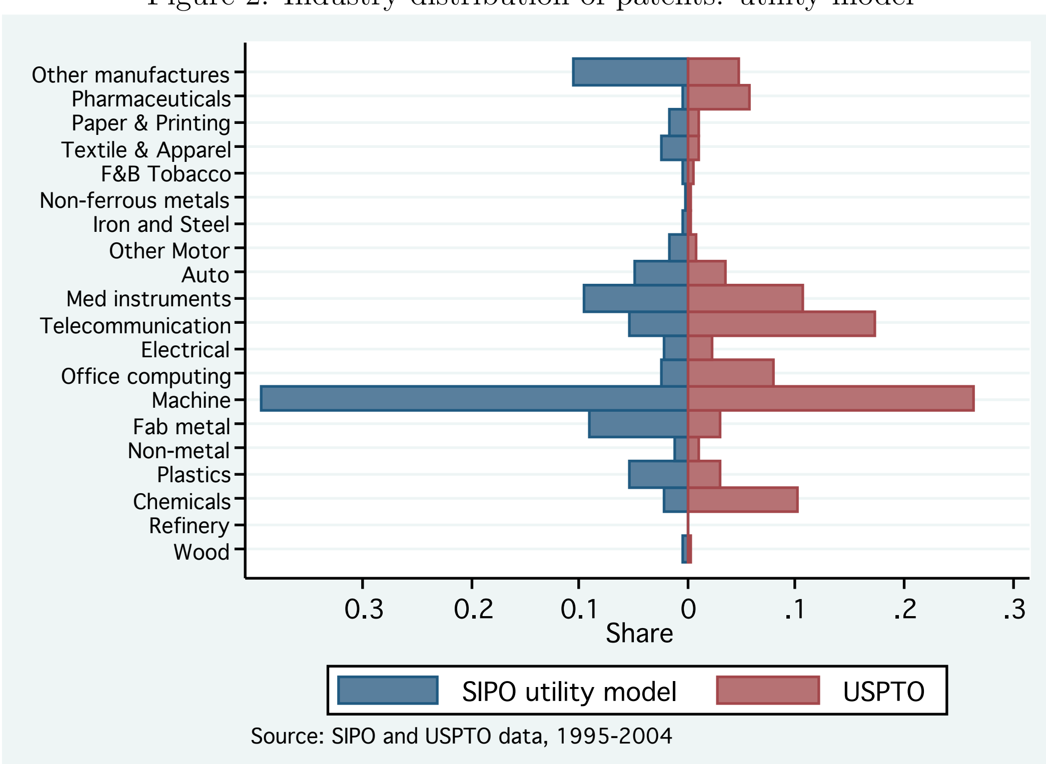


Figure 3: Industry distribution of SIPO invention patents

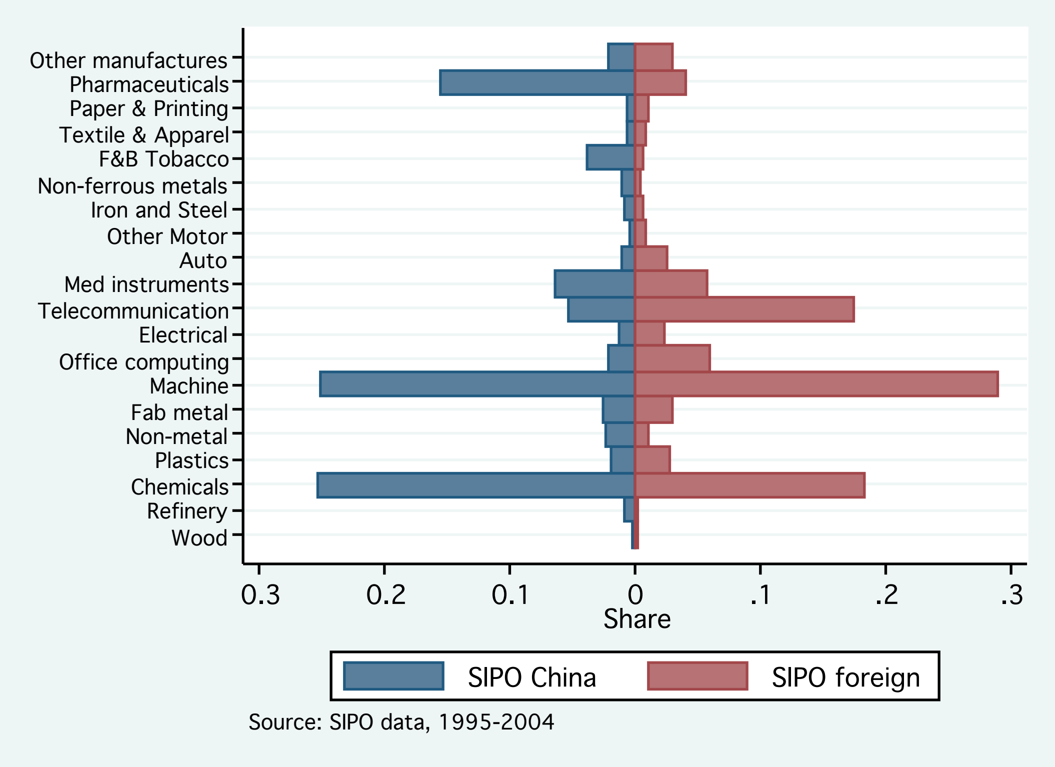
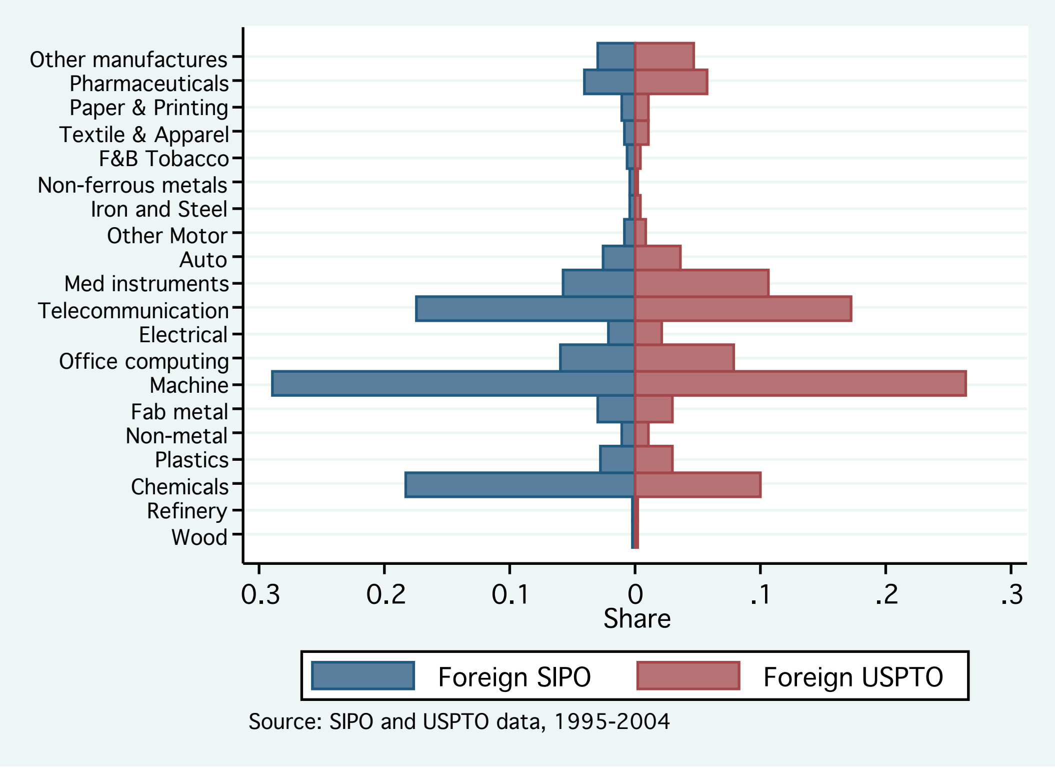


Figure 4: Industry distribution of foreign patents: SIPO v. USPTO



next three major patenting industries are chemicals (ISIC 24), telecommunications equipment (ISIC 32), and pharmaceuticals (ISIC 2423). At USPTO, telecommunications equipment, medical instrument (ISIC 33), and chemicals are the next three industries that patent most. Together the top three industries account for between 50 and 60 percent of all patents granted by the two patent offices.

A comparison of the distributions of SIPO utility model patents and USPTO patents in Figure 2 shows more differences between Chinese and theU.S.patents than Figure 1 does. The SIPO utility model patents are much more concentrated than USPTO patents - the lone spike of the machinery industry accentuates the difference. The SIPO utility model patents are much more concentrated than SIPO invention patents - machinery accounts for nearly 40 percent of all utility model patents,whereas it only accounts for less than 30 percent of invention patents. The Chemical industries account for nearly a quarter of invention patents, but only less than 10 percent of utility model patents.

Figure 3 compares the distributions of SIPO patents granted to Chinese and foreign inventors. While the dominant shares - close to half - of machinery and chemicals patents are a common feature of the two distributions, telecommunications equipment patents represent a much larger fraction of foreign inventors' patents than those of the Chinese inventors. On the other hand, almost 15 percent of the patents Chinese inventors take out are pharmaceutical patents, but for foreign inventors, the pharmaceutical's share is less than 5 percent.

Finally, I compare the distributions of foreign inventors' Chinese SIPO patents and their USPTO patents in Figure 4. Again the broad patterns are similar with some noticeable differences. Compared to the distribution of their USPTO patents, foreign inventors' Chinese SIPO patents are under-represented in pharmaceutical, medical instrument, and office computing patents are under-represented in the distribution of foreign inventors' Chinese SIPO patents. Chemical patents, on the other hand, are relatively over-represented.

4 Propensity to apply for Chinese SIPO patents

For firms operating globally or facing competition from foreign firms, it becomes necessary to decide if and in which country to seek patent protection.[8] Such decisions are only likely to become more frequent and challenging as the world economy becomes increasingly integrated. Whether a foreign firm files for a Chinese SIPO patent is determined by the cost of the patent application and the expected return from the patented technology in the Chinese market, which is in turn dependent on the nature and degree of competition the firm faces in China. Such competition can come from Chinese and other foreign firms.

Foreign patent applicants incur the direct costs of applying for a Chinese patent. These include the patent application fee paid to the Chinese SIPO.[9] Patent documents also need to be written in Chinese, which implies a translation cost for the foreign applicants. Once a patent is granted, it needs to be renewed annually to stay in effect.[10]

But perhaps more importantly, foreign patent applicants risk divulging information on their proprietary technology to the wouldbe imitators in China. While it is unclear how difficult it is for the Chinese imitators to access patent documents outside China, it is highly conceivable that publishing such patent applications in the Chinese language would substantially reduce the cost for the imitators to

[8]There is high correlation between patenting in the three jurisdictions of U.S., Japan, and Europe, but evidence with respect to other jurisdictions is lacking.

[9]Currently this cost is estimated to be around 4545 RMB, or 575 dollars, for an invention patent application that has three claims and whose application process goes through smoothly within two years.

[10]The renewal fee is on a graduated scale. For invention patents it is 900 RMB per year for the first three years, 1200 RMB for each of the next three years, eventually reaching 8000 RMB a year for the last four years of a patent's statutory life. See the SIPO website for details: http://www.sipo.gov.cn/sipo/zlsq/

learn of the patented technologies.[11] Such risk of information disclosure is likely to be exacerbated by a weak IPR regime. On the other hand, strengthening of the enforcement of IPR would lessen the risk and lead to greater propensity to patent.

The return from obtaining Chinese patents, to the extent that they are enforceable, arises from the monopoly rent the patent holder captures from preventing the imitation of her patented technology embodied in the product she markets and/or manufactures in China and from blocking the entry of potential competitors in the market. In general, there is a choice of covering the market of your product and covering the jurisdiction where the imitation might occur. Eaton and Kortum (1999) argued that the firms might choose to cover the market rather than the location of potential imitation given the mobility of capital and other manufacturing inputs. Given the non-rivalry nature of intellectual property, the return from patent protection is expected to be increasing in the scale of the patent holder's sales and manufacturing activity. For convenience of exposition, I will label this the market covering hypothesis.

Lastly, I propose the competitive threat hypothesis. The return from patent protection is also a function of the patenting choices of the foreign applicant's competitors in the Chinese market. The monopoly rents that the patent right promises may be significantly curtailed if the patent holder's competitors introduce products that are substitutes for her product. While the substitutability between patented products is regulated by the patent regime, consumers may find different patented products close enough substitutes for each other. As a result, patents become a strategic instrument for firms competing against each other in China. What and how many patents a firm takes out in China is therefore a function of what and how many patents other firms in China have taken out or are expected to take out. Without a structural model, I will not be able to determine a priori whether patents

[11] The Chinese patent law requires the publication of patent applications within 18 months of the filing date of the applications.

are strategic substitutes or complements. But instead of imposing too much structure on the data, I will let the data reveal the relationship between patents taken out by different applicants and therefore whether the strategic interaction plays a role in China's foreign patenting surge.

A corollary of the competitive threat hypothesis is that in the absence of competition, foreign firms might be less willing to patent new technologies in China at a rapid rate for fear of imitation and cannibalizing existing sales.

The number of patents a foreign country applies for and are granted in China is assumed to be proportional to the amount of new knowledge produced at home subject to an industry specific, potentially time-varying propensity to patent and the propensity to file for applications in China for some of the patents applied for in the home country.

$$P^C_{k,j,t} = f(S_{k,j,t}, P^H_{k,j,t}) \tag{2}$$

The number of Chinese SIPO patents granted to inventors from industry j of country k in year t, $P^C_{k,j,t}$, is a function of new knowledge produced by these inventors at home and the propensity to patent, which together are represented by the number of patents granted at home, $P^H_{k,j,t}$, and the term, $S_{k,j,t}$, which captures the propensity to patent in China. As the preceding discussion indicates, $S_{k,j,t}$ internalizes all the costs and benefits of applying for patent protection in China and therefore embodies the strategic impact of patenting.

5 What drives the foreign patenting surge in China? A first look

The primary objective of the paper is to investigate the propensity to patent in China of foreign applicants, i.e., $S_{k,j,t}$, in equation (2). I first relate $S_{k,j,t}$ to other countries's Chinese SIPO patent grants in the same technological field. Ideally I would like to use the number of patents granted in a foreign country's home market as a proxy for newly generated patented knowledge, $P^{H}_{k,j,t}$. The lack of such data forces me to use the foreign countries' USPTO patents instead. In the absence of theoretical guidance, I adopt the following log-linear equation to estimate the interaction between foreign countries patenting choices in China:

$$\ln P^{C}_{k,i,j,t} = \sum_{\substack{n=1 \\ n \neq k}}^{7} \alpha_n \ln P^{C}_{n,i,j,t} + \sum_{n=1}^{7} \beta_n \ln P^{U}_{n,i,j,t} + \gamma \ln \widehat{P}^{C}_{c,i,j,t} + g(D_i, D_t, D_i * D_t) + \upsilon_{k,i,j,t} \quad (3)$$

Where P is the number of invention patents, and superscripts C and U denote Chinese SIPO patents and USPTO patents respectively. n indexes seven countries or regions: China, Germany, Japan, Korea, Taiwan, U.S., and a control region, ROW, the rest of the world. $\widehat{P}^{C}_{c,i,j,t}$ is the number of Chinese SIPO utility model patents. I estimate equation (3) for each of the six k's, i.e., China, US, Japan, Germany, Korea and Taiwan. While I do not estimate the equation for ROW separately, as it is a synthetic and composite control, I include its number of Chinese SIPO patents on the right hand side. The industry, the IPC class (3-digit) within the industry, and the year of grant are subscripted by i, j, and t respectively. The last term on the right hand side of equation (3), $g(D_i, D_t, D_i * D_t)$, captures industry-specific and grant year-specific fixed effects and the full interaction of the two types of fixed effects, therefore controlling for industry-specific but time-varying effects.

An obvious challenge of estimating equation (3) with OLS is the potential simultaneity bias generated from external shocks driving the countries' patenting decisions in China. Given the paucity of appropriate instruments, I try to control for as many as possible factors that might correlate with a country's decision in applying for Chinese SIPO patents. Nevertheless the estimation results should be interpreted as correlations rather than indicating any causal effects. Equation (3) suggests that a country's Chinese SIPO patents is a function of the country's home granted patents, which I approximate with the country's USPTO patents. A full set of the countries' USPTO patents are included in each regression. The year and industry fixed effects help to capture determinants of propensity to patent such as China's macroeconomic policies, industry policies, the strengthening of patent protection in China, and other economy-wide macroeconomic shocks. More importantly, each regression also includes the interaction of the two types of fixed effects, thus allowing for industry-specific, but time variant effects. For example, the automobile industry might experience a supply or demand side shock in a given year. This would be captured by the interaction of the industry- and year- fixed effects.

The regression results are reported in Table 3. Columns 1, and 3 to 7 correspond to the estimation of equation (3) for China, U.S., Japan, Germany, Korea and Taiwan. The dependent variable of column 2 is the number of China SIPO utility model patents granted to Chinese applicants.

5.1 Chinese inventors' SIPO patents

The first two columns of Table 3 show that Chinese invention patents and utility model patents interact differently with the invention patents of other countries. While invention patents are all positively correlated with each other, China tends

Table 3: Interaction of Chinese and foreign patenting

	China_I	China_U	USA	Japan	Germany	Korea	Taiwan
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
P^C_{China}			-.023	0.108**	-.031	0.063*	0.137**
			(0.017)	(0.015)	(0.023)	(0.025)	(0.025)
$\widehat{P}^C_{China}$			-.129**	0.059**	-.033**	0.137**	0.078**
			(0.011)	(0.01)	(0.013)	(0.017)	(0.02)
P^C_{USA}	-.058	-.422**		0.124**	0.158**	0.177**	-.012
	(0.032)	(0.037)		(0.025)	(0.03)	(0.038)	(0.041)
P^C_{Japan}	0.252**	0.242**	0.15**		0.215**	0.488**	0.209**
	(0.033)	(0.036)	(0.027)		(0.033)	(0.048)	(0.043)
$P^C_{Germany}$	-.045	-.080**	0.114**	0.129**		-.097**	0.054
	(0.031)	(0.031)	(0.022)	(0.021)		(0.037)	(0.035)
P^C_{Korea}	0.056**	0.19**	0.075**	0.171**	-.057**		0.119**
	(0.019)	(0.023)	(0.016)	(0.016)	(0.021)		(0.023)
P^C_{Taiwan}	0.109**	0.106**	-.005	0.07**	0.03	0.114**	
	(0.02)	(0.028)	(0.017)	(0.015)	(0.02)	(0.022)	
P^C_{ROW}	0.241**	0.087*	0.456**	0.306**	0.642**	0.178**	0.147**
	(0.044)	(0.043)	(0.032)	(0.034)	(0.034)	(0.05)	(0.051)
P^U_{China}	0.236**	0.02	0.035*	-.018	0.033	-.015	-.022
	(0.02)	(0.024)	(0.014)	(0.014)	(0.02)	(0.024)	(0.024)
P^U_{USA}	0.107	0.785**	0.587**	-.023	-.121	-.090	0.02
	(0.071)	(0.093)	(0.062)	(0.058)	(0.063)	(0.08)	(0.084)
P^U_{Japan}	-.399**	-.683**	0.061	0.499**	-.102**	-.081	0.214**
	(0.04)	(0.041)	(0.036)	(0.028)	(0.037)	(0.049)	(0.046)
$P^U_{Germany}$	0.29**	0.233**	-.029	-.195**	0.593**	-.391**	-.309**
	(0.041)	(0.048)	(0.035)	(0.029)	(0.039)	(0.054)	(0.046)
P^U_{Korea}	0.026	-.373**	-.042	0.047*	-.011	0.581**	-.080*
	(0.031)	(0.034)	(0.025)	(0.024)	(0.031)	(0.039)	(0.036)
P^U_{Taiwan}	-.461**	0.558**	-.157**	0.032	0.007	0.061	0.28**
	(0.024)	(0.034)	(0.02)	(0.019)	(0.027)	(0.031)	(0.03)
P^U_{ROW}	0.631**	0.362**	-.103	-.308**	-.337**	-.179*	0.14
	(0.084)	(0.089)	(0.067)	(0.065)	(0.069)	(0.087)	(0.081)
Obs.	2385	2383	2381	2381	2381	2381	2381
R^2	0.887	0.856	0.934	0.948	0.915	0.874	0.861

All regressions include full sets of industry and year dummies and all the interactions of the two sets of dummies.
Robust standard errors are in parentheses.
* - significant at 95% level; ** -significant at 99% level

to take out more utility model patents in areas where Japan, Korea, and Taiwan receive more invention patents. On the other hand, Chinese patents seem to be negatively correlated with the U.S. and German patents, although the coefficients are only statistically significant in the case of Chinese utility model patents. Given that utility model patents represent more of imitation than innovation,[12] this result suggests that China seems to have been actively imitating the technologies of Japan, Korea, and Taiwan, much more so than they have been learning from the U.S. and German technologies.

While China's SIPO invention patents are positively correlated with the SIPO invention patents of Japan, Korea, and Taiwan, they are negatively correlated (with the exception of Chinese utility model patents and Taiwan's USPTO patents) or uncorrelated with these countries' USPTO patents in the same technological fields. In other words, these countries adopt different patenting strategies in China than in the U.S.: where they patent actively in China, they patent little in the U.S., and vice versa.

The differential interaction between Chinese and foreign industries' patenting in China may be due to the extent to which Chinese producers compete with their foreign counterparts in China. This is consistent with the pattern of China's bilateral trade relations with these countries. While the U.S. is China's largest export market and incurs a large trade deficit with China, China has been running the largest trade deficits with Japan, Korea and Taiwan.[13] Firms from these countries have significant contact with Chinese firms in the Chinese market through trade or investment and therefore want to protect their proprietary technologies in China. However, comparative advantage dictates that Chinese firms do not compete with

[12]That China's USPTO patents are correlated with China's SIPO invention patents but not with China's SIPO utility model patents confirms this perception.

[13]In 2003, China ran a trade surplus of 58.6 billion dollar with the U.S. and trade deficits of 40.3, 23, and 14.7 billion dollars respectively with Taiwan, Korea, and Japan, according to the statistics of China's National Statistical Bureau(www.stat.gov.cn).

Japanese, Korean and Taiwanese firms in the same U.S. market. Hence the negative correlation or lack of correlation between Chinese SIPO invention patents and these economies' USPTO patents. In other words, these patterns are what the market covering and the competitive threat hypotheses would have predicted.

A related interpretation of the finding that China's technology development tracks that of Japan, Korea and Taiwan rather than the U.S. and Germany is the appropriate technology hypothesis (Basu and Weil, 1998) and the absorptive capacity hypothesis (Cohen and Levinthal, 1990) regarding the process of technology diffusion. If one accepts the notion that individual patented technologies of U.S. and German inventors are more advanced and fundamental in nature than those of Japan, Korea and Taiwan, it should not be surprising that Chinese firms start by learning from their counterparts in the latter economies given their underdeveloped absorptive capacity. Chinese imitators may find it relatively easier to imitate the technologies adopted by Japanese, Korean, and Taiwanese industries in the Chinese market than those from the U.S. and Germany.

5.2 Foreign patenting in China

Symmetric to the pattern of how Chinese patents interact with foreign patents, only the Chinese SIPO patents of Japan, Korea and Taiwan are correlated with Chinese SIPO patents granted to Chinese inventors. Japanese and Taiwanese SIPO patents appear to be more closely correlated with Chinese invention patents than Chinese utility model patents; the pattern is reversed for Korean patents. The elasticity ranges from 0.059 to 0.137.

On the other hand, SIPO patents of Korea and Taiwan are most highly correlated with Japan's SIPO patents. In the case of Korea, the elasticity reaches 0.488, not far from the elasticity with its own USPTO patents of 0.581. Although the elasticity is much lower at 0.209 for Taiwanese SIPO patents, it is substantially higher than its correlation with any other country's SIPO patents. Again these patterns of interaction of patenting decisions are consistent with the patterns of trade between Japan, Korea, Taiwan and China.

The U.S. and Germany, on the other hand, are closer to each other and to Japan than they are to China, Korea, and Taiwan. Patenting by the U.S. and Germany is either negatively correlated or uncorrelated with Chinese utility model patents. This is consistent with the appropriate technology and absorptive capacity hypotheses. It also suggests that U.S. and German firms' patenting strategy in China is not necessarily just to block Chinese firms' imitation.

6 Imports, competition and foreign patenting

The preceding analysis using patent data alludes to potential roles played by the market covering and competitive threat motives in explaining China's foreign patent explosion. In this section I test these hypotheses explicitly by integrating data on China's imports from its trade partners into the analysis of foreign patenting in China. To properly account for the extent of the presence of a foreign industry in China and the degree of competition from other foreign industries in the Chinese market, I would need not just data on China's imports, but also data on foreign industries' sales in the Chinese market through their locally invested firms. The latter data are hard to obtain and are likely to contain much noise even if statistical agencies make them available.[14] Therefore, accepting that it is an imperfect measure, I use imports to construct measures of the need to cover market and the competitive threat from other foreign industries.

[14] For example, according to the Chinese National Statistical Bureau, the largest amount of foreign direct investment in China in 2004 originated in Hong Kong, followed by Virgin Islands. Cayman Islands invested more in China than Germany and Britain combined. Clearly the high rankings of the tax heavens make it hard to ascertain the real origin of most of the FDI coming to China.

6.1 Data on China's imports

The data on China's imports were retrieved from the World Bank Trade and Production Database.[15] A challenge that comes with using Chinese trade data is the need to consider the role of Hong Kong as an entrepot that used to intermediate a substantial portion of China's export and import, particularly the former.[16] However, in recent years, Hong Kong's importance in intermediating China's exports and imports has substantially diminished. The Chinese National Bureau of Statistics showed that Hong Kong's shares of mainland China's exports and imports fell from 24 and 7 percent respectively in 1995 to 17 and 2 percent in 2004.[17] These numbers also indicate that Hong Kong's intermediary role has been much less prominent in China's imports than exports.

6.2 Imports and patenting

I estimate the following equation to investigate the market covering and the competitive threat hypotheses in explaining China's foreign patenting surge:

$$\ln P^C_{k,j,t} = \beta_1 \ln I_{k,j,t} + \beta_2 \ln CI_{k,j,t} + \beta_3 \ln P^U_{k,j,t} + \beta_4 \ln P^C_{C,j,t} + \beta_5 \ln \widehat{P}^C_{C,j,t} + \mu_{k,j,t} \quad (4)$$

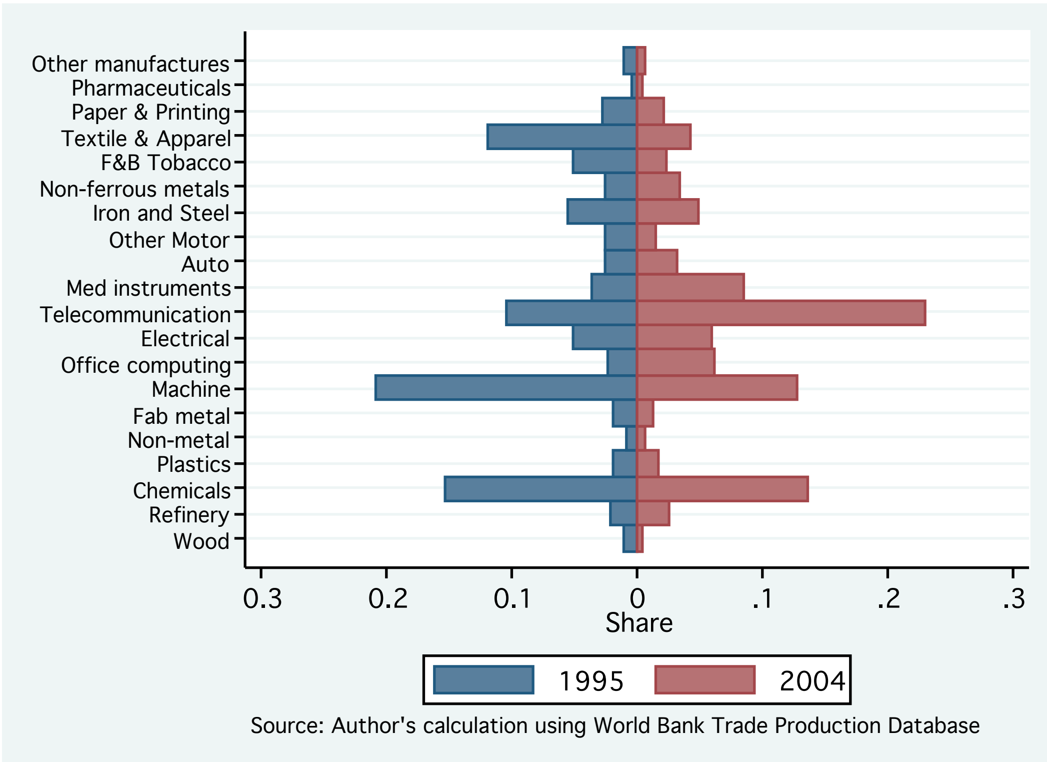
I assume that foreign patenting driven by market covering is proportional to China's import from the foreign industry, $I_{k,j,t}$, where k, j, t again denote country, industry, and year respectively. Competition from other foreign industries pose a threat to firms of a foreign industry and may prompt the latter to respond by adjusting its patent strategy. To derive a measure of the competition from other foreign industries in the Chinese market, I would ideally need to measure

[15] See Nicita and Olarreaga (2006) for detailed documentation of the database.

[16] Feenstra et al. (1999), for example, showed that properly accounting for China's re-exports to the U.S. through Hong Kong substantially reduced the discrepancy between the Sino-U.S. trade surplus reported by the Chinese and the U.S. governments.

[17] See the web site of the Chinese National Bureau of Statistics: www.stats.gov.cn.

Figure 5: Industry distribution of China's imports: 1995 and 2004



competition between the foreign industries at the product level. The two- and three- digit industry level import data I am using are too coarse for that purpose. Instead I am using information from the patent data to construct the following competing import measure:

$$CI_{k,j,t} = \sum_{l \neq k} TP_{k,l,j,t} I_{l,j,t} \tag{5}$$

The imports effectively competing with country k's export to China in industry j in year t is computed as the weighted sum of all the other countries' exports to China with the weights being the technology proximity between country k and the country (l) whose export to China is being weighted in an industry-year. The technology proximity between two foreign industries is computed at the four-digit IPC level. In estimating equation (4), I also experiment with using the un-weighted sum of all other imports, $TI_{k,j,t} = \sum_{l \neq k} I_{l,j,t}$, which I call the naive measure of competing imports.

Equation (4) also includes the number of patents granted to the foreign industry by the USPTO as a proxy for new knowledge produced by the industry. The numbers of Chinese invention and utility model patents are also included since the patent regressions in the previous section show that foreign industries do react to the patenting activity of Chinese inventors. The summary statistics of the regression variables are reported in Table 4.

Table 4: Summary statistics

Variable	Mean	Std. Dev.	N
$\ln P^C$	2.201	2.341	1511
$\ln I$	13.194	2.052	1560
$\ln TI$	15.802	1.295	1560
$\ln CI$	14.884	1.907	1509
$\ln P^U$	5.146	2.171	1560
lnP^C_C	4.081	1.485	1560
$\ln \widehat{P}^C_C$	6.436	1.592	1560

6.3 Estimation results and discussion

6.3.1 Polled OLS and fixed effect estimation

I first estimate equation (4) with OLS and include full sets of country, industry, and year fixed effects. The results are reported in the first two columns of Table 5. The model in column 1 uses the naive measure of competing imports to identify the competitive threat effect. Neither the foreign industry's own export to the Chinese market nor the sum of other foreign imports show any effect on the foreign industry's patenting in China. However, when the competing imports variable, $\ln CI$, is used in the place of the un-weighted sum of other foreign imports, there is strong evidence in support of the competitive threat hypothesis. The coefficient of the competing imports in column 2 indicates that if other foreign industries who compete in the same market, as determined by the closeness of their patent portfolios, increase their sales in the Chinese market by 10 percent, holding its own export constant, a foreign industry is likely to increase its Chinese SIPO patents by 4.6 percent.

While the country-, industry- and year- specific effects are soaked in the respective dummies, there could still be country-industry specific effects that might be correlated with the right hand side variables. For example, the Japanese automobile industry had been initially competing in the Chinese auto market largely through exports, whereas the German auto manufacturers were early movers in manufacturing in China. To account for such country-industry-specific effects, I estimate equation (4) with an OLS fixed effect estimator. Instead of using the "demeaning" approach, I obtained the fixed effect estimates through a least-square dummy variable (LSDV) approach. The results are reported in columns (3) and (4) in Table 5.

While the own import variable remains statistically insignificant, the naive measure now becomes statistically significant with a negative sign. The coefficient of the weighted competing imports variable, on the other hand, remains almost unchanged both in terms of statistical significance and magnitude. In column (4), the own import variable turns negative and statistically significant, which is contrary to the market covering hypothesis, i.e., controlling for competing imports, the more a foreign industry sells in the Chinese market, the more incentive it has to protect its proprietary technology.

This seemingly paradoxical result can be rationalized by taking into account the corollary of the competitive threat hypothesis. Holding competing imports constant, the more a foreign industry exports to China, the greater the returns to market covering, but it also implies that the foreign industry would have more market power, or at least a larger market share, and presumably less competition.

The strong correlation between foreign patenting in China and foreign patenting in the U.S. that I found in Table 3 is reaffirmed by the economically and statistically significant coefficient of the foreign industry's patent grants in the U.S. Foreign patenting is also significantly correlated with the number of SIPO invention patents granted to Chinese inventors, although the magnitude of the correlation is much smaller than that of foreign industries' own Chinese and U.S. patents. China's utility model patents, on the other hand, is uncorrelated with foreign patenting in China, echoing the earlier results in Table 3. The model fits the data quite well, explaining 90 percent of the variation in the dependent variable.

Table 5: Imports and foreign patenting

	OLS		Fixed effect		SYS-GMM	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln I$	-.021	-.027	0.11	-.190**	-0.118	-.203*
	(0.032)	(0.027)	(0.06)	(0.042)	(0.195)	(0.086)
$\ln TI$	-.061		-.350**		0.128	
	(0.079)		(0.083)		(0.253)	
$\ln CI$		0.460**		0.458**		0.272**
		(0.048)		(0.04)		(0.083)
$\ln P^U$	1.117**	0.826**	1.944**	1.275**	0.359*	0.387*
	(0.08)	(0.06)	(0.128)	(0.103)	(0.156)	(0.135)
$\ln P_C^C$	0.268**	0.261**	0.269**	0.262**	0.330**	0.298**
	(0.102)	(0.069)	(0.077)	(0.059)	(0.116)	(0.101)
$\ln \widehat{P}_C^C$	0.023	0.044	-.078	0.053	0.107	-0.166
	(0.351)	(0.239)	(0.246)	(0.19)	(0.250)	(0.209)
Obs.	1511	1509	1511	1509	1390	1387
R^2	0.894	0.93	0.917	0.945		
Hansen χ^2					108.23	105.78
d.f.					117	117
Prob.					0.707	0.762
AR(1)					-4.590	-4.890
Prob.					0.000	0.000
AR(2)					2.210	1.340
Prob.					0.027	0.181

Robust standard errors are in parentheses.
* - significant at 95% level; ** -significant at 99% level

6.3.2 GMM estimation

The GMM estimators that Arellano and Bond (1991) proposed provide an alternative to the conventional fixed effect estimator. The basic estimation strategy is to assume that the error term in equation (4) has two components, a time invariant fixed effect and an AR(1) term. That is,

$$\mu_{k,j,t} = \eta_{k,j} + \xi_{k,j,t}, \quad \text{and}$$

$$\xi_{k,j,t} = \rho\xi_{k,j,t-1} + \tau_{k,j,t}$$

where $\tau_{k,j,t}$ is an *iid* error term. After first differencing equation (4), I treat each time period as a separate equation and use all lags that are more than two periods old as instruments for the first differences. Blundell and Bond (1998) proposed some additional moment conditions that involve the identifying assumptions that contemporaneous levels and lagged differences are orthogonal to each other. Together these moment conditions form the system GMM estimator. The results reported in columns (5) and (6) of Table 5 were obtained using a two-step procedure in which the moments weighting matrix was obtained after the estimation of the first-round covariance matrix. Robust standard errors are reported in parentheses.

In column (5) where the naive measure of competing imports is used, neither import variable is statistically significant. The results are broadly similar to the OLS results in column (1) except that the magnitude of the elasticity of Chinese patenting by foreign industries with respect to their USPTO patents has substantially diminished in size and is now only significant at the 5 percent level. Chinese utility model patents remain insignificant in explaining foreign patenting in China.

Turning to the correct model in column (6), as in the case of fixed effect estimation, competing imports has a significant and positive effect on foreign patenting in China, although the magnitude of the impact has declined from 0.458 to 0.272. The negative coefficient of own import from the fixed effect estimation carries over to the GMM estimation, but it has lost some of its statistical significance and is now significant at the 5 percent level.

In the bottom of Table 5, I report a number of diagnostic statistics to verify the validity of the model and the instruments. The Hansen test is a χ^2 over identification test that checks the overall validity of the instruments. In both cases, I am unable to reject the null hypothesis that the instruments are collectively valid. By model construction and assumption, the error terms are correlated to the first order, but not the second order. The AR(1) and AR(2) test statistics confirm this.

In sum, by estimating the patenting and imports equation (4), I find that competing foreign imports have a robustly positive effect on foreign patenting in China, with an elasticity of between 0.272 and 0.46. Own import is found to have a weakly negative to nil effect on the industry's patenting in China. One possible explanation is that once competing imports are controlled for, the more a foreign industry sells to the Chinese market, the larger its market share. Market power may discourage foreign firms from seeking patent protection in China for two reasons. First, market power enhances the foreign firms' ability to appropriate returns to their proprietary technologies. The foreign firms with market power may also slow down the introduction of new technologies to the Chinese market to avoid cannibalizing existing sales.

China's total import has been growing at an annual rate of 16 percent over the last decade. The point estimate of the patents-competing imports elasticity implies that growing import could have contributed to between 21 and 36 percent of annual growth of foreign patenting in China.

The result that the propensity of foreign inventors taking out Chinese invention patents is higher in areas where Chinese inventors intensively take out invention patents also carries through. Thus, overall, the estimated effect ranges from 0.26 (OLS) to 0.3 (GMM), all significant at the 1 percent level. That is, when domestic Chinese invention patents increase by 10 percent in a technology area, we are likely to see that foreign patenting in the same area increasing by 2.6 to 3.3 percent. On the other hand, there is no evidence that would suggest any interaction between foreign patenting and domestic Chinese utility model patents. But unlike in the case of the interaction between foreign inventors, I cannot pin down this interaction to market competition without information on the degree to which foreign and domestic Chinese firms compete against each other.

7 Concluding remarks

I set out to understand what is behind the increasing propensity of foreign inventors to apply for Chinese patents even when the legal ramifications of such patents might be dubious. The key hypothesis is that the propensity to patent of an inventor is in part determined by the patenting decision of her competitors. The competition between foreign firms in the Chinese market and the competitive threat from Chinese domestic firms may lead these foreign firms to accelerate technology transfer to the Chinese market and hence the need to use Chinese patents to protect such technologies. The empirical exercise seeks to differentiate two specific hypotheses regarding the determinants of foreign inventors' propensity to patent in China: the market covering hypothesis and the competitive threat hypothesis.

Using a variant of the Yale Technology Concordance, I mapped the Chinese SIPO and USPTO patents to industries where such patented technologies are likely to have been invented. Regressions using these industry level patent grants showed that even after determinants of patenting such as knowledge production, propensity to patent, and the strength of China's IPR regime are controlled for, there is significant correlation between patents granted to foreign countries and between foreign patents and those granted to domestic Chinese applicants. The imitating effort of Chinese firms, measured by the utility modle patents, tracks closely the invention patents granted to inventors from Japan, Korea and Taiwan, rather than the U.S. and Germany. That China imitates the technologies of its East Asian neighbors also suggests that the latter's technology may be more appropriate than those of the U.S. and Germany for Chinese firms to adopt given their underdeveloped absorptive capacity.

Recognizing that these patterns of correlation are consistent with what the patterns of bilateral trade between China and these countries would have predicted, I related foreign patenting in China to China's imports from these countries. A robust result is that increase in competing imports leads a foreign industry to increase its patenting in China, lending support to the competitive threat hypothesis. On the other hand, after controlling for competition from other foreign industries, there is no evidence that expansion of an industry's own sales in China increases its propensity to patent. That is, there is no support for the market covering hypothesis. The incentive to seek patent protection for an industry's increasing sales in the Chinese market could be offset by the market power of the industry that may encourage it to put off introducing new technologies in China.

Strengthening IPR protection has increasingly become a precondition for developing countries to integrate into the global network of trade and investment. A policy implication of the findings here is that maintaining a competitive market environment, in addition to its effect on product market competition, may further ameliorate the costs of instituting a stringent IPR regime by accelerating the adoption of new technologies in the developing country by developed country firms

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