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

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KDI International Seminar
Intellectual Property and Economic Development
February 18-19, 2010

China's foreign patent explosion

	China SIPO				U.S. PTO	
	Invention		Utility model		Utility	
	Growth rate 1995-04	Count 2004	Growth rate 1995-04	Count 2004	Growth rate 1995-04	Count 2004
China	25.6%	15,733	9.0%	60,561	20.8%	404
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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	30.1%	49,054	9.1%	68,889	5.4%	164,293

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

Research questions

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- Market covering hypothesis
- Competitive threat hypothesis
  - Competition from Chinese industries: imitation and innovation
  - Competition from other foreign industries in China

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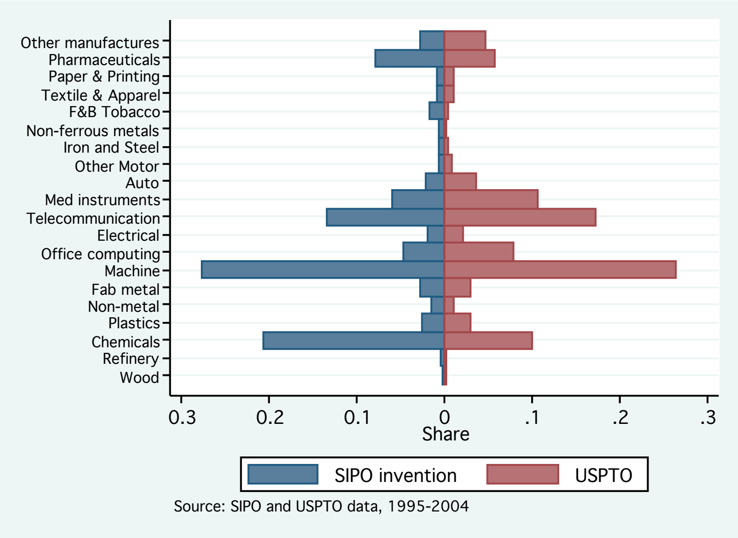
  - 1963 - 2004: 3,750,000 patents

Matching patents to industry

- Yale Technology Concordance
  Canadian Patent Office: 1972-1995, 300,000 patents; *IPC* class $\longrightarrow$ *SIC* (industry of manufacture and sector of use)
- OECD Technology Concordance
  SIC $\longrightarrow$ *ISIC*

Industry distribution of patents: invention



Foreign patenting in China

- Determinants of foreign patenting

$$P^C_{k,i,t} = f(S_{k,i,t}, P^H_{k,i,t-1})$$

- Partial correlation estimates

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

Interaction of Chinese and foreign patenting

	China_I	China_U	USA	Japan	Germany	Korea	Taiwan
P^C_{China}			-.023 (0.017)	0.108** (0.015)	-.031 (0.023)	0.063* (0.025)	0.137** (0.025)
$\hat{P}^C_{China}$			-.129** (0.011)	0.059** (0.01)	-.033** (0.013)	0.137** (0.017)	0.078** (0.02)
P^C_{USA}	-.058 (0.032)	-.422** (0.037)		0.124** (0.025)	0.158** (0.03)	0.177** (0.038)	-.012 (0.041)
P^C_{Japan}	0.252** (0.033)	0.242** (0.036)	0.15** (0.027)		0.215** (0.033)	0.488** (0.048)	0.209** (0.043)
$P^C_{Germany}$	-.045 (0.031)	-.080** (0.031)	0.114** (0.022)	0.129** (0.021)		-.097** (0.037)	0.054 (0.035)
P^C_{Korea}	0.056** (0.019)	0.19** (0.023)	0.075** (0.016)	0.171** (0.016)	-.057** (0.021)		0.119** (0.023)
P^C_{Taiwan}	0.109** (0.02)	0.106** (0.028)	-.005 (0.017)	0.07** (0.015)	0.03 (0.02)	0.114** (0.022)	
P^C_{ROW}	0.241** (0.044)	0.087* (0.043)	0.456** (0.032)	0.306** (0.034)	0.642** (0.034)	0.178** (0.05)	0.147** (0.051)

Interaction of Chinese and foreign patenting: continued

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**
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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

Results

- Chinese invention and utility model patents track those of Japan, Korea, and Taiwan, but not those of America and Germany.
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Imports and foreign patenting

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ln $\hat{P}_C^C$	0.023 (0.351)	0.044 (0.239)	-.078 (0.246)	0.053 (0.19)	0.107 (0.250)	-0.166 (0.209)
Obs.	1511	1509	1511	1509	1390	1387
R^2	0.894	0.93	0.917	0.945		

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Concluding remarks

- Patents taken out by different countries in China are correlated beyond what technology opportunity and changes in macro economic environment would predict.
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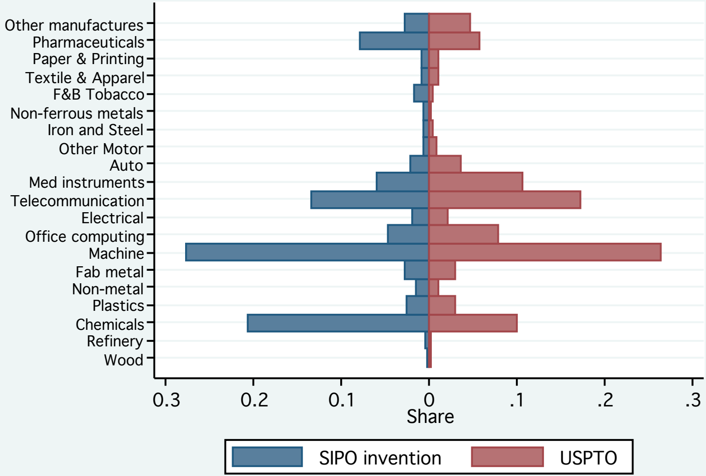

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Abstract

Foreign applications for Chinese patents have been growing by over 30 percent a year. This paper explores two hypotheses in explaining the foreign patenting surge in China: market covering and competitive threat. With foreign companies more deeply engaged with the Chinese economy, returns from protecting their intellectual property in China have increased. As domestic Chinese firms ability to imitate foreign technology gains strength and competition between foreign firms intensifies in the Chinese market, such competitive threat creates an urgency for protecting intellectual property. Using a database that comprises China's State Intellectual Property Office patents and the U.S. Patent and Trademark Office patents, I find strong support for the competitive threat hypothesis. The estimates imply that competition between foreign firms in China can account for 36 percent of the annual growth of foreign patenting in China.

*I thank for their helpful comments and discussions Wes Cohen, Adam Jaffe, Gary Jefferson, Lucio Picci and Liu Xielin. I am particularly indebted to Alessandro Nicita for providing the ISIC rev3 version of the World Bank Trade and Production database and to Lim Kwang Hui for help with retrieving the latest USPTO patent data from the NUS Patent Database. Li Jia provided superb research assistance. Financial support from the NUS Academic Research Grant (R-122-000-091-112) is gratefully acknowledged. Part of the paper was written during the author's visit to the International Business School of Brandeis University, 2006-07. I am grateful to the host's hospitality. The usual caveat applies.

1 Introduction

Foreign applications for patents issued by China's State Intellectual Property Office (SIPO) have seen explosive growth. From 1995 to 2004, foreign - primarily OECD and the Asian newly industrialized economies - applications for and grants received of Chinese invention patents had been growing at over 30 percent a year.[1] Of these applications, over ninety percent have claimed foreign priority, which implies that patent applications had earlier been filed for the invention with a foreign jurisdiction. During the same period of time, patent applications at the U.S. Patents and Trademark Office were growing at about 5% a year. Apparently foreign inventors are seeking to protect an increasing proportion of their patents in China.

A number of forces could have contributed to the 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 other foreign firms in the Chinese market. It is hard to assess how the efficacy of intellectual property rights (IPR) enforcement in China has evolved over the years. Reported incidences of IPR violation might be a result of strengthened enforcement that leads to better detection of violation as well as rampant piracy. I will have little to say about the patent enforcement mechanism in China, and to the extent that it is an economy-wide concern, it will not be central to my industry-level analysis. I will instead focus on the other potential explanations.

As foreign firms expand and deepen their engagement with the Chinese economy, whether through FDI or international trade, the risk of exposing their in-

[1] Hu and Jefferson (2009) 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.

tellectual property to potential imitation and misappropriation increases. At the same time, the need to introduce newer and more sophisticated technology in the Chinese market also grows. Therefore the propensity of foreign firms to patent in China is expected to go up over time. This is the market covering hypothesis.

A firm's decision of whether to apply for patents in China is also dependent on her competitors' patenting decisions. 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. To gain a strategic advantage such as blocking entry, foreign firms are likely to raise the level of their patenting activities in China as their competitors become more productive in imitating and innovating or more aggressive in introducing new technologies invented elsewhere.

The changing propensity to patent of foreign inventors has welfare implications for China. If higher propensity to patent correlates with greater incidence of foreign technology being deployed in China, the foreign patent explosion suggests more intense technology transfer to China; on the other hand, if the increased propensity to patent merely represents efforts by foreign inventors to strategically preempt the entry of competition, the welfare implication may largely take the form of larger barrier to technology diffusion.

I compile a database of the 1.37 million patents that China's SIPO has granted from 1985 to 2004. I also create a corresponding sample for the U.S. Patent and Trademark Office granted patents. Using these data, 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 foreign patenting surge at China's SIPO. In the following section, I delineate the market covering and competitive threat hypotheses. Section 4 briefly discuss the methodology of mapping patents to industries using the OECD Technology Concordance. In Section 5 I estimate a patenting equation to assess the nature and intensity of the interaction between various countries' patenting activities in China. I explicitly test the two hypotheses in Section 6 by using imports data to construct a measure of competition between foreign firms in China. Section 7 concludes with observations of policy implications.

2 China's foreign patenting surge

China's patent law, re-instituted in 1985, has undergone two major amendments in 1993 and 2001 respectively. These amendments have largely brought the Chinese patent legislation into international norms, at least on paper.[2] Despite the general perception of weak enforcement of the patent law, foreign inventors' enthusiasm for applying for Chinese patents has only strengthened. Table 1 compares and contrasts patenting activity at the Chinese SIPO and the USPTO The economies that have been granted the most patents by SIPO and USPTO are listed 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.

China's foreign patenting surge is evident in terms of both the absolute growth rate and the growth rate relative to that of USPTO patents. From 1995 to 2004, invention patents, which are the equivalents of utility patents at the USPTO, had been growing at over 30 percent annually; the growth rate of USPTO patents was 5.4%. Since over 90% of the patents have claimed foreign priority, the much faster rate of foreign patenting in China than in the U.S. implies that the foreign patent-

[2]The appendix provides a comprehensive description of China's patent system.

ing surge at SIPO 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	
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3 Propensity to apply for Chinese SIPO patents

Whether a foreign firm files for a Chinese SIPO patent is determined by the cost of and the expected return from the patent application, 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[3] and the costs of engaging a patent attorney. Patent documents also need to be written in Chinese, which entails a translation cost for the foreign applicants. Once a patent is granted, it needs to be renewed annually to stay in effect.[4]

[3]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.

[4]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

An indirect cost is that foreign patent applicants risk divulging information on their proprietary technology in China. This cost can be significant when the underlying foreign patent application is still pending in the jurisdiction where the application was first filed.[5] Such risk of information disclosure is likely to be exacerbated by a weak IPR regime.

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. I will label this the market covering 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, with the substitutability between patented products being regulated by the patent regime. The strategic motive to block the entry of potential competition or to gain other strategically advantageous position gives rise to the competitive threat hypothesis.

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/

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

4 Matching patents to industries

Patent data compiled by patent offices do not indicate 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).[6] 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.[7]

4.1 The OECD Technology Concordance

The OECD Technology Concordance originated from the Yale Technology Concordance (Evenson and Johnson, 1997; Kortum and Putnam, 1997). From 1972 to 1995, the Canadian Patent Office assigned, in addition to the international patent classes (IPC), which is an internationally adopted system of taxonomy that characterizes the technology areas patents fall, an industry of manufacture and a sector of use for each of the over 300,000 patents it granted. This patent database thus provided the natural input to construct a concordance between patent classes and

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

[7]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/

industry of manufacture and sector of use of the patents. Assuming that such concordance remains stable over time and across countries, the Yale Technology Concordance 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, 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.

I aggregate SIPO patent data to ISIC industries using the OECD Technology Concordance, which assigns to each IPC patent class a probability that patents from this IPC class belong to a three- or four- 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 OECD Technology Concordance does not cover all IPC classes - to three- or four- digit ISIC industries. With the concordance, I map both SIPO and USPTO patents to an industry of manufacture.[8]

4.2 Industry distribution of patents

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 describe manufacturing industry distribution of the SIPO and USPTO patents.

Figure 1 contrasts industry distributions of SIPO invention patents and USPTO patents. The two distributions look broadly similar. For both SIPO and USPTO,

[8] The USPTO started IPC patent class assignment in 1975, although the USPTO patent data are available from 1963.

Figure 1: Industry distribution of patents: invention

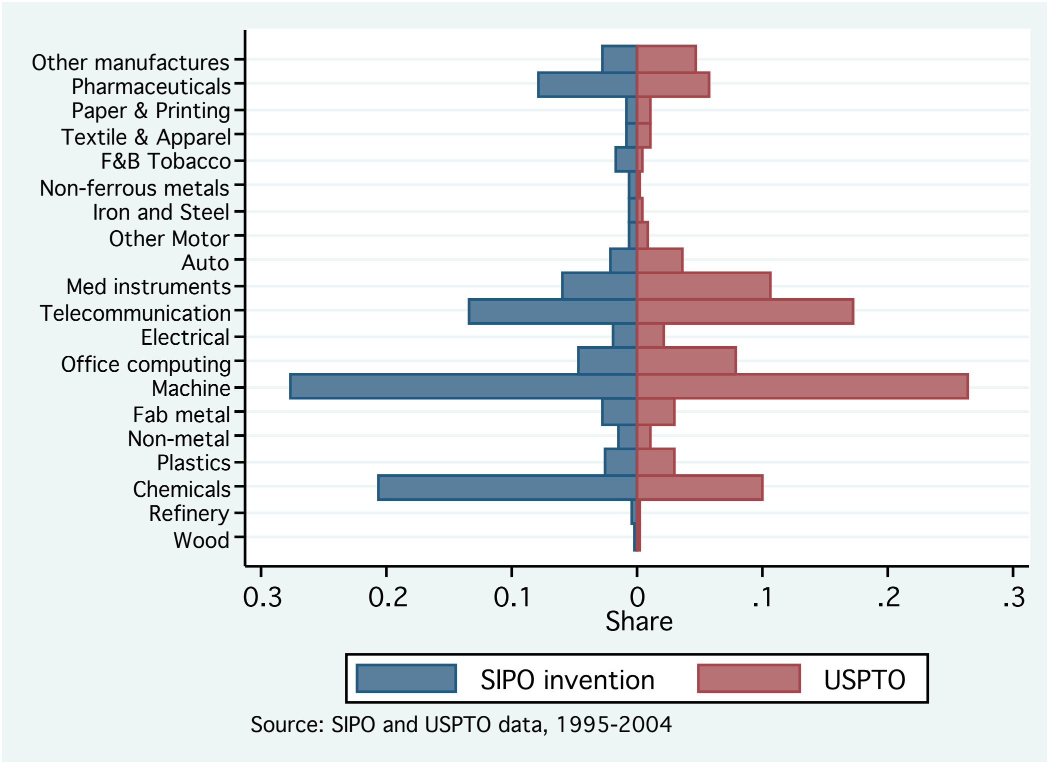
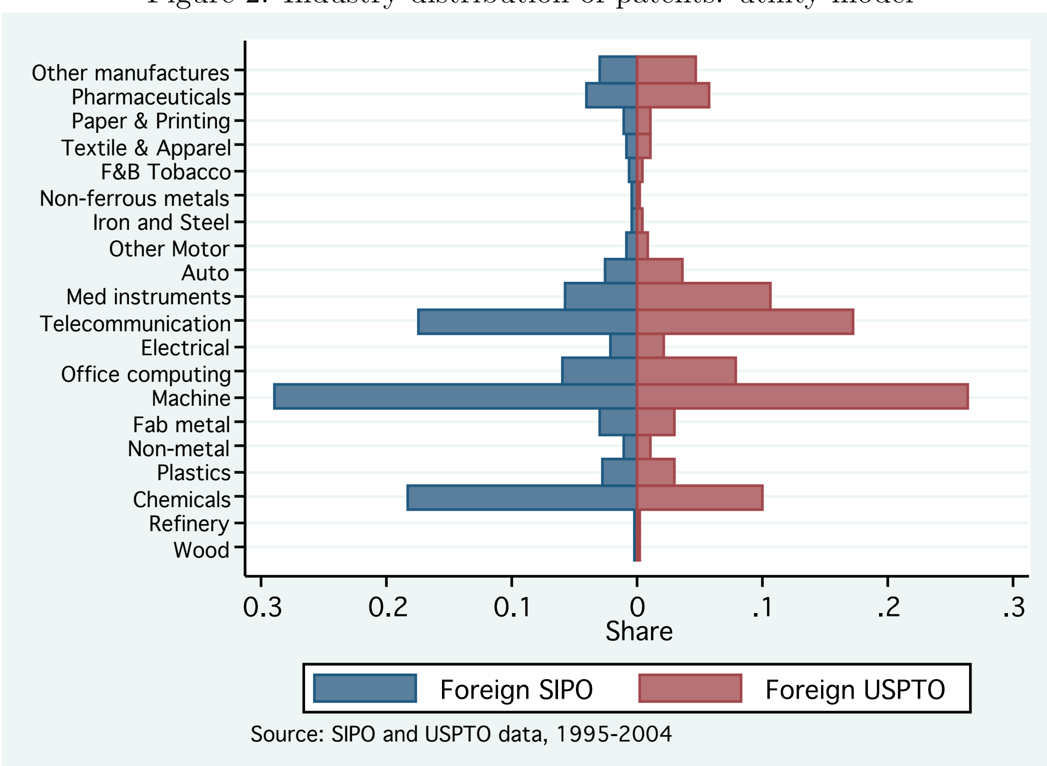


Figure 2: Industry distribution of patents: utility model



the largest share of patents go to the machinery industry (ISIC 29). For SIPO, the 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.

I compare the industry distributions of foreign inventors' SIPO patents and their USPTO patents in Figure 2. Again the broad patterns are similar with some noticeable differences. Relative to the distribution of their USPTO patents, foreign inventors' Chinese SIPO patents are under-represented in pharmaceutical, medical instrument, and office computing. Chemical patents, on the other hand, are relatively over-represented.

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

The number of patents a foreign country applies for 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.

$$P^C_{k,j,t} = f(S_{k,j,t}, P^H_{k,j,t}) \quad (1)$$

The number of SIPO patents that inventors from industry j of country k applied for 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.

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:

$$\ln P^C_{k,i,j,t} = \sum_{\substack{n=1 \\ n \neq k}}^{7} \alpha_n \ln P^C_{n,i,j,t} + \sum_{n=1}^{7} \beta_n \ln P^U_{n,i,j,t} + \gamma \ln \widehat{P}^C_{c,i,j,t} + g(D_i, D_t, D_i * D_t) + \upsilon_{k,i,j,t} \tag{2}$$

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 (2) 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 application are subscripted by i, j, and t respectively. The last term on the right hand side of equation (2), $g(D_i, D_t, D_i{*}D_t)$, captures industry-specific and application 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 (2) with OLS is the potential simultaneity bias generated from external shocks driving the countries' patenting decisions in China. Given the lack of appropriate instruments, I try to control for as many as possible factors that might correlate with a country's decision in applying for SIPO patents. Nevertheless the estimation results should be interpreted as correlations rather than indicating any causal effects. Equation (2) suggests that a country's 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, changes in China's patent regime, 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 (2) 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 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

Table 2: 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

are only statistically significant in the case of Chinese utility model patents. Given that utility model patents represent more of imitation than innovation,[9] 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.

The differential interaction between Chinese and foreign patenting in China may be due to the extent to which Chinese producers compete with their foreign counterparts in China and seems 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.[10] 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. 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

[9]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.

[10]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).

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 SIPO patents of Japan, Korea and Taiwan are correlated with 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.

Finally, as is anticipated, the self-correlations, i.e., correlations between countries' SIPO patenting and their USPTO patenting, are large and robust for all countries.

6 Imports, competition and foreign patenting

In this section I explicitly test the market covering and competitive threat hypotheses 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.[11] 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.

6.1 Data on China's imports

The data on China's imports were retrieved from the World Bank Trade and Production Database.[12] 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.[13] 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.[14]

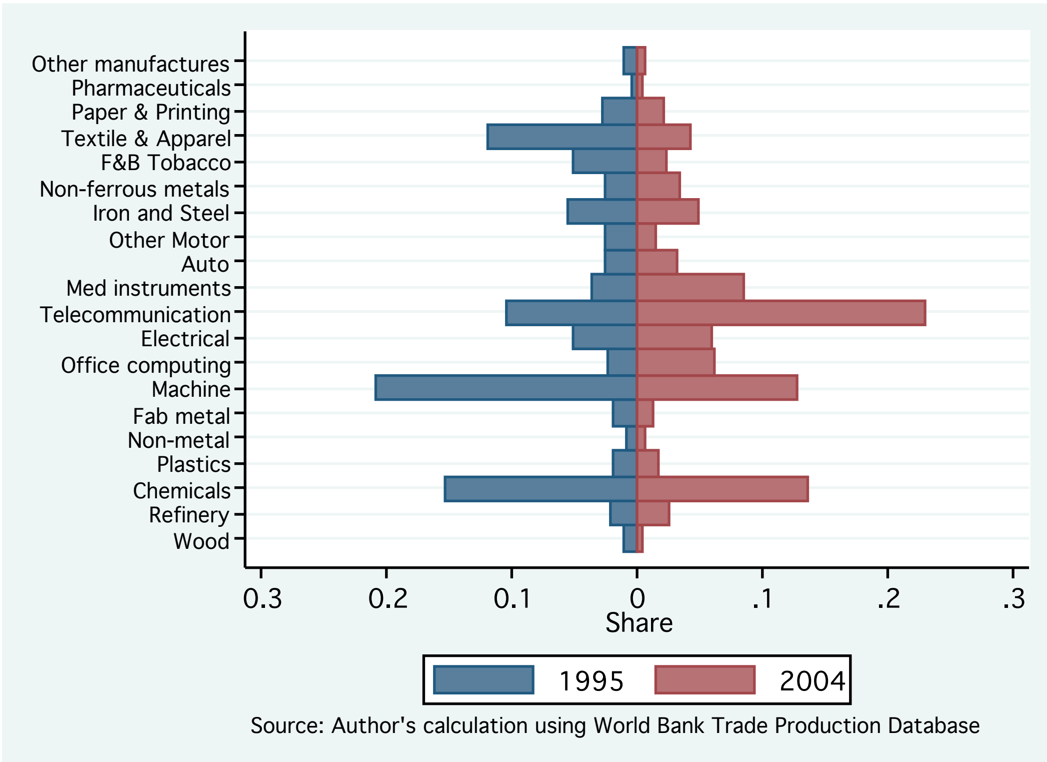
[11]For example, according to the Chinese National Statistical Bureau, the largest amount of foreign direct investment in China in 2004 originated in Hong Kong, followed by Virgin Islands. Cayman Islands invested more in China than Germany and Britain combined. Clearly the high rankings of the tax heavens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

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

[13]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.

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

Figure 3: Industry distribution of China's imports: 1995 and 2004



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:

$$\ln P^C_{k,j,t} = \beta_1 \ln I_{k,j,t} + \beta_2 \ln CI_{k,j,t} + \beta_3 \ln P^U_{k,j,t} + \beta_4 \ln P^C_{C,j,t} + \beta_5 \ln \widehat{P}^C_{C,j,t} + \mu_{k,j,t} \quad (3)$$

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. To derive a measure of the competition from other foreign industries in the Chinese market, I would ideally need to measure 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 use information from the patent data to construct the following competing import measure:

$$CI_{k,j,t} = \sum_{l \neq k} TP_{k,l,j,t} I_{l,j,t} \tag{4}$$

The imports effectively competing with country k's export to China in industry j in year t, $CI_{k,j,t}$, is computed as the weighted sum of all the other countries' exports to China, $I_{l,j,t}$, 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, $TP_{k,l,j,t}$. The technology proximity between two foreign industries is computed as an un-centered correlation between the patent distribution over four-digit IPC classes, i.e., $TP_{k,l,j,t} = \frac{V'_{k,j,t} V_{l,j,t}}{\sqrt{V'_{k,j,t} V_{k,j,t}} \sqrt{V'_{l,j,t} V_{l,j,t}}}$, where $V_{k,j,t}$ is a vector of patent class shares of country k's SIPO patent applications in year t.[15]

In estimating equation (3), I also construct an 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 (3) 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 included to capture competitive threat from domestic Chinese firms. The summary statistics of the regression variables are reported in Table 3.

[15] 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 3: 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 effects estimation

I first estimate equation (3) with OLS and include full sets of country, industry, and year fixed effects. The results are reported in the first two columns of Table 4. 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 I replace the naive measure of competing imports with the technology proximity weighted one, there is strong evidence to support 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. This represents foreign inventors' incentive to apply for SIPO patents in addition to their motive to protect their market in China.

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 (3) with an OLS fixed effects estimator.[16] 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 was reported 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.

[16] A Hausman test has been conducted and clearly rejects the random effects model.

Table 4: 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 estimator of Arellano and Bond (1991) provides an alternative way to estimate equation (3). The basic estimation strategy is to assume that the error term in equation (3) 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 (3), 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 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 4 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 4, 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 (3), 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 to 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. 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 unique database that comprises information on the Chinese SIPO and USPTO patents and a concordance that maps patent classes to industries, I find significant correlation between patents granted to foreign countries and between the patenting decisions of foreign inventors in China and that between domestic Chinese and foreign inventors. The imitating effort of Chinese firms, measured by the utility model patents, tracks closely the invention patents granted to inventors from Japan, Korea and Taiwan, rather than the U.S. and Germany. These patterns of correlation are consistent with what the patterns of bilateral trade between China and these countries would have predicted and may have been dictated in part by China's under-developed absorptive capacity.

To differentiate the market covering and competitive threat hypotheses, 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, there is no evidence that expansion of a foreign country's own sales in China increases its propensity to patent once the industry- and country- wide shocks are controlled for. That is, there is no support for the market covering hypothesis.

The result that the foreign patenting surge in China has largely been driven by the competitive threat motive rather than covering market suggests that the surge may represent more strategic preemption and blocking of competitors than larger number of new, foreign-invented technologies being deployed in China. This tilts the traditional tradeoff of a patent system in favor of higher reward to patent owners and greater barriers to technology diffusion. Further research is necessary to shed light on the welfare implications.

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APPENDIX

China's patent system

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. 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.

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.[17]

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). On the other hand, the Chinese central government seems to have taken steps 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.

[17]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.