Speed of Patent protection, Rate of Technology Obsolescence and Optimal Patent Strategy Evidence from Innovations Patented in U.S, China and several other countries

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Abstract

When technology develops faster, how would inventors adjust their patenting strategies? Using a dataset that combines information of innovation applied both in China and U.S, we find inventors are willing to secure early patent grant when technology moves ahead faster. The conventional wisdom that patent secures a flow of monopoly profit that depreciates at a constant speed over time is not consistent with our empirical findings. We think the profit flow can be characterized as either "front loaded" or "back loaded". Faster technology progress shifts the profits towards early periods of patent life, making early grant more important. The empirical results suggest a more flexible patent regime that differs in terms of grant delay is more efficient.

1 INTRODUCTION

This paper considers the effect of technology obsolescence on patenting strategies (choices of the appropriate type of patent) by Chinese technology inventors. In many countries, delay in patent examination creates a significant wedge between the time when firms pursue IP protection and the time they get it. If new inventions are introduced into the market at a constant pace, individual's patenting strategies should remain uniform overtime. In contrast, when technologies move faster, the demand for patent also changes. In this case, the urge to draw licensing contract, signal product image or prevent imitation may drive inventors away from slowly granted patent. We create a novel way of measuring technology obsolescence by exploiting time variations in patent renewal decisions. We then link this measure with a sample of Chinese patents of which the inventors have chosen either a fast-grant patent (but short protection period and high enforcement risk) or a slow-grant patent. Despite the diverse purposes of pursuing for IP protection across different technology areas, we find when a technology advances more quickly, the demand for swift patent also increases. Moreover, the effect of technology obsolescence depends on firm (inventor) characteristics. Swift patent grant is of particular importance for firms with almost no stock of intellectual property whereas firms with large patent portfolios respond little to changes in technology obsolescence. The findings suggest that heterogeneity of technology characteristics in an important consideration of measuring the effectiveness of patent protection, and a flexible IP regime may stimulate R&D for a broader scope of innovations.

The primary goal of patent system is to provide incentive to innovate. In many countries, there is a long delay between patent application and grant. Given that patent is enforceable only after grant, this delay means that the effective patent life is constrained from the "front." It has been well recognized that heterogeneity in the speed of development of inventions across technologies means that the delay in patent grant will be of little concern for some inventions but a serious issue for others. In the extreme, if new and marginally improving inventions can be introduced to the market long before the PTO (patent office) can grant the patent, patents can be very inefficient in promoting R&D (research and development). Companies, such as Apple, IBM, Microsoft, Nokia etc. relies heavily on software patent for licensing and cross licensing agreements. Since software products are usually developed and launched within months, if not weeks, speed of patenting is crucial to the success of commercialization.

In this paper, we investigate the effect of the rate of technology obsolescence on inventor's demand for patent protection. First we provide a simple theoretical model to formalize the intuition. In product R&D of a non-cumulative "quality ladder" type, new discoveries in research laboratories push forward the prior art, eventually replacing current products and eliminating their market value. Hence, the effective life of patents on some product is constrained from the "back" by technology improvements. A higher rate of technology obsolescence, therefore, corresponds to a stronger demand for fast patent protection.

Second, we empirically investigate the economic insight of the basic model by specifically selecting inventions disclosed in patent applications in two patent examination systems (patent dyads). We choose two patent dyad datasets: inventions that have been filed patents both in China and the United States (henceforth SIPO-USPTO patent dyad), and both in China and at the European Patent Office (henceforth, SIPO-EPO patent dyad). SIPO, the State Intellectual and Patent Office of China, provides two major types of patent protection for product innovations: invention patents and utility models. Compared to invention patents, utility models are granted significantly faster[1]. It should be noted that the short examination delay of utility model is at the cost of no substantial examination[2]. Previous studies have pointed out that utility model is designed to serve as a stimulus to domestic inventive activities, and to protect minor innovations (Bosworth and Yang 2000). The evidences suggest, in China, patent applicants in general choose utility model because they do not have inventions that are innovative enough to be granted invention patent. However we focus on patents that are included in SIPO-USPTO and SIPO-EPO patent dyads. This selection has two advantages. The USPTO and EPO employ a uniform and rigorous patent examination standard. Patentability standards are presumably at least comparable to the patentability standard for invention patent at SIPO[3] . Furthermore, application fees at USPTO and EPO are much higher than those at SIPO[4]. Thus the *ex-ante* private values of these inventions should at lease exceed the minimum values of invention patents in China.

It should be noted that the USPTO offers a fast track (Track One) patent examination that guarantees office action within 12 months of patent application. Perhaps, a more direct way to empirically examine the effect of rate of technology obsolescence on the optimal patent choice is to examine whether inventors in fast-moving technology fields have higher propensity of filing fast track patents in U.S. compared to inventors in other tech-areas. However, since the policy was implemented in mid 2011 and is relatively new, we were unable to acquire a dataset sufficiently large to conduct interesting econometric analyses.

The previous literature offers no consensus measure of the rate of technology obsolescence. We employ the patent renewal decisions to create a proxy variable for the rate of technology obsolescence. Although individual patent renewal decisions reflect primarily the value of the patent to the inventor, an aggregate measure at the technological level should reflect the rate at which new and marginally superior technology emerges. When the incumbent technology's competitive advantage diminishes due to emergence of better technology, the private value of the associated patent will also decrease, increasing the probability of earlier patent abandonment. Although the speed of technology development should follow

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[1] Utility models are granted, on average, 6 months after application. Invention patents are granted about 30 months after application. Author's own calculation based on SIPO patent dataset 2010.

[2] Grant of utility model only requires preliminary check of formality. See e.g. *Patent Law of the People's Republic of China 2008.*

[3] The grant of invention patent at SIPO requires substantial examination of novelty, non-obviousness and practicability. See e.g. *Patent Law of the People's Republic of China 2008.*

[4] The application fee at USPTO for a (non-provisional) patent is over 6 times of that for invention patent, approximately 12 times of that for utility model, at SIPO.

similar patterns across the world, each country should have its unique patterns in technological progress due to differences in market development. The measure of rate of technology obsolescence, therefore, should be measured by using patents filed within the same country. We classify all U.S. granted patents by (application) year and technology fields (3-digit USPC classification code). Within each category, we then calculate the percentage of patents that are abandoned within a fixed amount of years after grant. The higher the portion of patents abandoned at a younger age, the faster the technology progresses. We use this percentage as our proxy variable for the rate of technology obsolescence at the cohort-technology area level[5].

In our econometric model, the effect of rate of technology obsolescence on choice of optimal patent protection (Chinese invention patent and Chinese utility model) is identified by exploiting the within-technology variation of the technology obsolescence over time. A key advantage of this approach is that it mitigates concerns of comparing patenting behaviors in different technology fields. As discussed extensively in the literature, the effectiveness of patents varies significantly in different technology areas. Patents have been perceived to be most effective in Pharmaceuticals; its effectiveness diminishes in other technology areas, noticeably Electrics and Electronics. Since such factors can affect applicant's patenting strategies, it is very difficult to interpret the econometric results in a regression without controlling for technology fixed effects.

Although we are primarily interested in applicant's patenting behavior in China, we specifically choose our measure of technology obsolescence to be calculated based on patents in a foreign patent office. A key advantage of this approach is that it avoids empirical ambiguity of simultaneous country level technology opportunities. If new research opportunities arise exogenously in a given technology field, then all applicants in that area will conduct more R&D and may change their patenting choice decisions, an effect that may be erroneously picked up by our empirical regression if we measure our technology obsolescence using SIPO patent renewal information. In contrast, we use foreign patents to calculate the rate of technology obsolescence so that point estimate will have a clear interpretation. This is because variation in technology obsolescence determines applicant's patenting choice decisions, while technology opportunities are theoretically independent across countries, allowing us to capture the effect of universal technology obsolescence separately from country-specific technology opportunities even if both are happening simultaneously.

Using this data, we find that-consistent with the theoretical model-in technology fields where new technologies emerges at a faster pace, inventors have a higher probability of choosing Chinese utility model patent to protect their innovation. More specifically, one standard error increase in the rate of technology obsolescence will increase the propensity to choose a utility model by 15%to 18% (the mean percentage of utility models in our data is 18%). This pattern is more striking during the periods when SIPO processes invention patents particularly slowly.The second finding is also consistent with our model: a longer delay in patent grant further constrains effective patent life from "front", causing inventors to shift towards faster patent protection in faster moving technology fields.

The idea that a uniform patent system might distorts innovation has been discussed in previous literature. For example, Budish, Roin, and Williams 2013 discusses how a fixed patent term could distort research incentives. But to our best knowledge, this paper is the first to theoretically and empirically demonstrate the inventors' heterogeneous demand for speed of patent protection. This topic relates to the previous literature on the discussion of optimal patent regime with respect to maximizing social welfare. Previous studies have pointed out that a uniform patent system provides distorted R&D incentives to firms and causes misallocation of resources across industries (Cornelli and Schankerman 1998; O'Donoghue and Zweimüller 2004). The existing literature focuses primarily on the U.S. and European patent system

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[5] Another method of calculating technology cycle is proposed by Bilir (2013), who uses mean forward citation lag at cohort-technology level.

and hence does not pay much attention on the utility model patents. Japanese and Korean scholars emphasize evaluating invention patents in their own countries[6]. This study will contribute to the literature by analyzing an less-understood patent policy that exists in over 70 patent-issuing countries in the world.

The potential contribution of this research is three-fold. First, previous theoretic literatures have primarily discussed the optimality of patent system through design of appropriate patent length and patent breadth (Nordhaus 1969; Gilbert and Shapiro 1990, Klemperer 1990; Green and Scotchmer 1995; O'donoghue, Scotchmer, and Thisse; O'Donoghue 1998, Koo and Wright etc.). This research introduces another aspect of patent value, the speed of patent protection, and how its interactions with length and breadth effect the efficiency of patent system as well as social welfare. Second, we define the rate of technology obsolescence by the percentage of abandoned patents applied in the same year and technology field. We can then measure the technology obsolescence index according to this definition and investigate the impact of rate of technology obsolescence on firms' demand for speed of patent protection. To our knowledge, no previous studies have conducted similar quantitative analysis. Third, USPTO recently launched the "three-track examination" [7] .Our study offers early insights on the likely response of inventors to the "three-track" system at USPTO.

The paper proceeds as follow: section 2 lays out the details of our theoretical model; section 3 discusses our definition of the rate of technology obsolescence; section 4 describes our data and summary statistics of all regression variables; section 5 reports our empirical results; section 6 reports our robustness checks; section 7 investigate welfare implication of our theory; section 8 concludes.

2 Chinese Invention Patent and Utility Model

The Chinese patent law was enacted in 1984 and put into practice in 1985. Two types of patent protection for industrial product innovation are available in China, namely the invention patent and the utility model. Before the first amendment of the Chinese patent law in 1992, the invention patent was protected for 15 years and the utility model patent 5 years from date of filing. The first amendment lengthened the terms for invention patent and utility model to 20 years and 10 years, respectively. The second amendment, which was completed in 2000, allowed state owned enterprises to trade their patents in the technology market. It also provided more incentives for employees to innovate. The third amendment, undertaken in 2008, increased the patentability standard to the "absolute novelty." It also made the SIPO more responsible in preparing a evaluation report for utility models.

The invention patent is the conventional patent: the application will go through a substantial examination of novelty, inventiveness and practicability. The protection period is 20 years from the date of filing or priority. The Chinese utility model was designed following the German and Japan utility model. This less-known form of IP protection was designed to provide property right that is less expensive, quick and easy to obtain. Faster protection under the utility model is achieved as no examination is required. As a result, the delay in utility model grant typically ranges from six months to one year, as against three to four years for invention patent. The protection period for utility model is 10 years from date of filing.

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[6] See e.g. Gallini and Scotchmer (2002) for an excellent literature review for the optimal design of patent system.

[7] The program allows applicants, willing to pay additional special fees ($4,950 for large entities and $2,550 for small entities) to request for prioritized examination that guarantees a final decision within twelve months of the filing date (Track 1). Applicants can also request a delayed examination for up to 30 months (Track 3), or the standard examination (Track 2).

Utility model is also more attractive as it requires considerable less amount of filing, lawyer and renewal fees. Interviews with lawyers working at big law firms located in Beijing, Guangzhou and Hong Kong indicate that hiring a lawyer to prepare for an invention patent application typically will cost the application \$1,300 (8000 rmb) while the cost for utility model is about \$ 500 (300 rmb). After an invention patent or utility model is granted at SIPO , the patentee needs to pay an annual renewal fee to keep the patent in force until the maximum statutory term. The renewal fee is generally increasing linearly over time. The annual renewal cost for utility model patent is about 60% that of invention patent. Since application for utility model does not require examination, the application fee for utility model is also significantly lower. Overall, the total cost of applying a utility model is around 30% of the cost of applying for invention patent.

Despite these advantages, utility models are harder to enforce than invention patents. When a utility model patent is filed for infringement litigation, the plaintiff is required to present a search report prepared by SIPO during the proceeding as evidence supporting its validity. However, before 2009, the credibility of the search report is subject to many concerns. PTO personnels in charge of preparing the search report are selected from a pool of examiners that do not represent the most qualified examiners in each technology fields. The resources accessible for prior art search is also limited to prior Chinese invention patents and utility models which precludes patents in foreign countries, academic journals and other online sources of publication. Moreover, the function of search report is to provide supportive evidence that the utility model might be considered novel and inventive. That is to say, even if the search report fails to find the utility model invalid, other evidences might still be.

To summarize, compared to the Chinese invention patent, the Chinese utility model represents a faster, cheaper however weaker IP protection.

3 Setup

In this section, I develop a model that captures the essential trade-off between getting a fast but weak (in terms of length and breadth) patent and a slow but strong patent, for the same innovation. For notation ease, I will call the slow, strong patent the Tier 1 patent and the fast, weak patent the Tier 2 patent. The cost differences between these two types of patents is subsumed from the model as they do not provide further insight. The model I discuss here is applied under the assumption of no cumulative product innovation in a quality ladder setting. Similar to Nordhaus (1969), Gilbert and Shapiro (1990) Gallini (1992) etc, the patent right serves to secure a flow of profits of which the size depends on patent attributes strength. To highlight the importance of speed of patent protection, I add in another variable that depicts the delay of examination. The optimal choice between Tier 1 and Tier 2 patent is based on an *ex-ante* (pre-filing) profit flow comparison: since Tier 2 patent is granted early, it secures profits primarily in the early periods of patent life while Tier 1 patent secures profits in later periods. The model formalizes the intuition that the relative effectiveness between patents is affected by changes in the rate of technological obsolescence. In the last part, I discuss the relevance of this model in the presence of strategic patenting.

I assume firms compete $R\&D$ in a number of technology areas indexed by j, $j = 1, \cdots J$. Technology areas are characterized by the rate of technology obsolescence STD_j, which I assume is exogenous to individual firms. Success in research labs can later be developed into commercially viable product innovations that represent the highest quality among all existing horizontally differentiated products. When some research centers achieve technological breakthrough, the state of art is pushed forward. A new Innovation thus has market value to its owner until the technology(s) it's utilizing becomes obsolescent and is replaced. When the current technology becomes obsolescent, I assume the associate product will lose its economic value to customers and the intellectual property (formal and/or informal) will lose its private value to the owner. Time is continuous.

For simplicity, I assume the firm has already decided to seek patent instead of informal mechanisms[8] to protect the innovation[9]. The firm's problem is to select the appropriate patent that maximizes *ex-ante* flow of profit. I assume imitation can eat away patentee's per-period oligopoly profit depending on the extent of patent scope[10]. The rate of technology obsolescence determines the maximum periods of oligopoly the patentee can enjoy. Higher STD_j corresponds to shorter periods of oligopoly and thus shorter periods of effective patent life. When the application is still pending, the applicant do not have the legal patent right which often result in delayed business cooperation and blank threat of potential infringements. The ex-post profit is therefore also affected by how early the patent can be issued[11]. In this model, I assume patent examination delay is exogenous to the applicants. Hence, applicants can expedite patent examination only through filing the fast patent.

Suppose a patent application is filed to PTO at $t = 0$, a patent protection can be written as a triple: (t, b, T), where t is the starting period of effective patent right (the date of patent allowance). b is the breadth of patent and can take value in the interval $[0, 1]$. $b = 0$ corresponds to a zero-effectiveness patent that allows imitation at 0 cost; $b = 1$ corresponds to perfect patent protection that blocks imitation until the end of patent life. T is the ending period of statutory patent. The rate of technology obsolescence STD_j is defined as a patent value depreciation factor: ρ_j. Higher rate of technology obsolescence correspond to a higher ρ_j which makes the oligopoly profits depreciates at a faster pace. In addition, I assume there is a non-zero patent maintenance cost c for each effective period until the patent expires. In this model, the renewal cost will determine the patent "shut-down" period[12].

Immediately following this setup, $(0, 1, +\infty)$ represents the strongest possible patent protection (immediately granted, largest breadth and infinite periods). With such patent, I assume a patentee's innovation will reward him with a per-period oligopoly profit of π until the technology becomes obsolescent and replaced which is determined by ρ_j and c. In the last period while the patent is renewed, the marginal profit must equal the marginal cost:

$$\pi \cdot e^{-\rho}T = c \tag{1}$$

$$\Leftrightarrow \quad T = \frac{1}{\rho} \cdot log\frac{\pi}{c} \tag{2}$$

Notice under strongest patent protection, the effective patent life is not infinite. The length of the patent depends on the rate of technology obsolescence, the per-period oligopoly profit and the patent renewal cost. Patentees would prefer longer patents when technology moves slowly, per-period profits are larger or the patent maintenance cost is lower.

Since faster, broader and longer patents always secure higher profit, it suffices to compare differences in profits under a faster but "weaker" patent with that under a slower but "stronger" patent. Define two distinct types of patent protections:

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[8] Some of the most frequently used tacit mechanisms include secrecy, lead-time advantage, complementary assets etc. citation here

[9] A fully-saturated model should compare the relative efficiency in terms of recouping returns to R&D between each pair of the IP mechanisms. However, what is important in my empirical analysis is whether the relative efficiency between fast-weak patent and slow-strong patent changes with exogenous variations in the rate of technology obsolescence. The simplified model stated above will only miss the case when the tacit mechanism, e.g. secrecy is always preferred to patent no matter how fast the technology moves.

[10] Gallini (1992) discussed the extent of patent breadth as measured by imitation cost. Alternatively, Klemperer (1990) defined the patent breadth as the spacial product differentiation. Gilbert and Shapiro (1990) defined it instead as the patentee's ability to raise price.

[11] Although examination is partly affected by applicants respond to referee reports, most of the time delay can be attributed to PTO administration and backlog frictions. (citation here)

[12] At major PTOs in the world, patent renewal fees are increasing over time. Assuming increasing renewal fees will only add redundant math derivation without introducing further insight into the model.

Tier 1 (t_1, b_1, T_1) and Tier 2 (t_2, b_2, T_2) with the following relations: $t_2 < t_1$, $b_2 < b_1$, $T_2 < T_1$ and $t_1 < T_2$. The first three conditions indicate that Tier 2 patent is granted earlier with a narrower breadth and shorter protection length than Tier 1. The fourth condition shows that the protection horizons of the two patents have certain overlaps. This condition, although not essential to the model, is consistent with the current two-tier patent policy designs in most countries.

With a Tier 1 patent, the discounted sum of profits is:

$$\Pi_{T_1} = \int_{t_1}^{min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c})} e^{-rs}(b_1\pi \cdot e^{-\rho s} - c)ds \tag{3}$$

where r is the discount factor. Similarly, with a Tier 2 patent, the discounted sum of profits is:

$$\Pi_{T_2} = \int_{t_2}^{min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})} e^{-rs}(b_2\pi \cdot e^{-\rho s} - c)ds \tag{4}$$

Using (3) and (4), the profit difference under alternative patent protections is:

$$\begin{aligned} \Pi_2 - \Pi_1 &= \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi \cdot e^{-\rho s} - c)ds \\ &- \int_{t_1}^{min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})} e^{-rs} \cdot ((b_1 - b_2)\pi \cdot e^{-\rho s})ds \\ &- \int_{min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})}^{min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c})} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds \end{aligned}$$

Tier 2 patent offers more profits in the earlier periods because it is granted earlier, $t_2 < t_1$. However, Tier 1 patent offers more per-period profits $(b_1 > b_2)$ as well as longer periods of protection $min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c}) > min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})$. It is therefore straightforward to see that Tier 2 patent will outperform Tier 1 patent if and only if the differences if profit of the early periods outweighs the differences in profits during later periods. Notice that (5) is weakly increasing in T_1. That is, if the Tier 1 patent is granted faster, the advantage of Tier 2 patent will become smaller. If the Tier 2 patent is not protected for too long and the Tier 1 patent not granted too slowly, for sufficiently small ρ and sufficiently large T_1, $\Pi_2 - \Pi_1 < 0$ and patent applicant will prefer Tier 1 patent to Tier 2 patent.

Lemma 1. *If (1) the statutory patent life for Tier 2 patent, T_2 is short enough; (2) the delay in Tier 1 patent, t_1 is quick enough, such that the following regularity condition holds:*

$$e^{-rt_2} \leq e^{-rt_1} + e^{-rT_2} \tag{5}$$

There exist ρ and T_1 such that $\Pi_2 - \Pi_1 < 0$.

Proof: please see appendix for details of proof.

In other words, patent applicant will prefer the Tier 1 patent since the majority of the flow of profit will pours in during the later periods of the patent life (small ρ) which will be missed by Tier 2 patent. This roughly corresponds to the case of the Pharmaceutical industry or the technology field of Medicals and Drugs (as defined in HJT) as Pharmaceutical firms generally renew their patents to full term since most of the profits is secured during the later periods of patent life (citation for Hatch-waxman act).

When the rate of technology obsolescence becomes larger, the per-period profits depreciates at a faster speed. This makes Tier 2 patent more favorable since Tier 2 patent secures early periods of profit. Simultaneously, Tier 1 patent becomes less attractive as because profits in the late periods might even fall short of the patent renewal costs.

Proposition 1. *If Lemma 1's regularization and the following regularity conditions hold:*

$$\frac{b_2\pi}{c}^{-(\frac{rt_1}{logb_1\pi - logc})+1} - \frac{b_1\pi}{c}^{-(\frac{rt_1}{logb_1\pi - c})+1} + e^{-(rt_1+logb_1\pi-logc)} - e^{-(rt_2+\frac{t_2}{T_1}(logb_1\pi-logc))} > 0 \tag{6}$$

$$\frac{1}{t_1}log\frac{b_2\pi}{c} > \frac{1}{T_1}log\frac{b_1\pi}{c} \tag{7}$$

$\Pi_2 - \Pi_1$ *is increasing in* ρ *when* $\frac{1}{t_1}log\frac{b_2\pi}{c} > \rho > \frac{1}{T_1}log\frac{b_1\pi}{c}$*;* $\Pi_2 - \Pi_1$ *is increasing in* ρ *when* $\Pi_2 - \Pi_1 < 0$*. In addition, there exists* ρ_* *such that* $\Pi_2 - \Pi_1|_{\rho_*} = 0$ *and* $\forall\rho > \rho_*$, $\Pi_2 - \Pi_1|_\rho > 0$*, making Tier 2 patent more favorable.*

Proof: Please see appendix for details of proof.
The conditions described in $Lemma$ and $Proposition 1$ regulates the exogenous variables (t_1, b_1, T_1) and (t_2, b_2, T_2) such that either Tier 1 patent or Tier 2 patent will be more preferable under specific rate of technology obsolescence. If either condition fails, then either Tier 1 or Tier 2 patent will always be the optimal choice, making the comparison meaningless.

Based on this simple setup, however, the model predicts that faster rate of technological obsolescence tends to make Tier 2 patent more attractive than Tier 1 patent only when $\frac{1}{t_1}log\frac{b_2\pi}{c} > \rho > \frac{1}{T_1}log\frac{b_1\pi}{c}$. This set of inequalities have an interesting economic interpretation. $\rho > \frac{1}{T_1}log\frac{b_1\pi}{c}$ corresponds to the range of technology obsolescence that applicants will not renew their patents to Tier 1's maximum statutory life. $\frac{1}{t_1}log\frac{b_2\pi}{c} > \rho$, on the other hand, refers to the range of obsolescence that will reward applicants with positive net per-period profits for some periods after the Tier 1 patent is issued. Only within this range of obsolescence will $\Pi_2 - \Pi_1$ be strictly increasing in ρ. Empirically, in major PTOs, on average less than 10% of patents will be renewal to the maximum term and less than 2% of patents will be abandoned before or immediately after patent issue (citation for U.S, SIPO, EPO statistics for patent life). Thus, our model is able to predict the behaviors of patent strategy in a wide range of technologies. The result shown in $Proposition 1$ is the main hypothesis of my empirical exercise.

Since Tier 2 patent is a registration model, the assumption that t_2 is fixed seems to be plausible. (citation here for China, Germany, Japan and Korea utility model registration process delay.) On the other hand, in major PTOs, backlog, thorough check of novelty and non-obviousness based upon existing prior art, communication frictions, the extent of examiner's diligence etc. are creating a significant variation in terms of Tier 1 patent examination (cite here for data on U.S, EPO and SIPO patent examination variation). The assumption that t_1 is fixed is likely to fail. It is thus important to understand whether changes in Tier 1 patent examination efficiency is likely to influence the effect of technological obsolescence on propensity to choose Tier 2 relative to Tier 1 patent.

Given the rate of technological obsolescence ρ fixed within $[\frac{1}{T_1}log\frac{b_1\pi}{c}, \frac{1}{t_1}log\frac{b_2\pi}{c}]$, a slower examination of Tier 1 patent will definitely make Tier 2 patent more favorable. Since the differences in profits is a continuous function of ρ, there exists a group of marginal "ρ" applicants (compilers) who are willing to shift from filing for Tier 1 patent to Tier 2 patent when t_1 increases. Larger t_1, therefore, corresponds to a smaller range of ρ applicants that find Tier 1 patent more favorable.

Proposition 2. *Suppose the regularity conditions in Lemma 1 and Proposition 1 hold. Let* ρ_1 *and* $\rho_{1'}$ *denote the rates of technological obsolescence that make applicants indifferent between choosing Tier 1 and Tier 2 patent when Tier 1 patent's examination delay is* t_1 *and* $t_{1'}$*, respectively. If* ρ_1 *and* $\rho_{1'}$ *both lie in* $[\frac{1}{T_1}log\frac{b_1\pi}{c}, \frac{1}{t_1}log\frac{b_2\pi}{c}]$, $t_{1'} > t_1$ *if and only if* $\rho_{1'} < \rho_1$*. Thus, increasing* t_1 *will make Tier 2 patent more favorable for a larger range of* ρ *applicants.*

Proof: please see appendix for more details.

A rich set of literature has discussed upon the issue of strategic patenting especially after the "pro-patent" shift with the establishment of CAFC (Court of Appeals of the Federal Circuit) by Congress in 1982. Patents are reported to be relatively inefficient in terms of appropriating returns to R&D among a list of formal and tacit mechanisms (Cohen citation). The intention to patent differs by firm characteristics. Firms with large patent portfolios exploits patent rights for preemptive purposes (citation for Gilbert, and maybe others?), strengthening cross-licensing bargains (Hall and Ziedonis, Cohen and maybe others?), defense against potential litigations (citations here? Hall and others??) etc. Firms with little or no formal IP foundations emphasize on fast patent grants, "iron-clad" patents for purposes such as securing VC fundings, licensing agreements, signaling strong R&D abilities and enhancing competition potentials.

The ability to protect IP is influenced by patent portfolio characteristics. Specifically, a firm can enhance protections on a particular patent (application) by threatening rivalries and imitators with his other patents. Firm can also preempt rival's entry by filing "sleeping patents" or creating "thickets" of patents. The ability to file patent for strategic purposes is largely influenced by the stock of patent owned by the firm. Technology obsolescence is thus likely to have differential effects on patenting strategy across firms with heterogeneous patent portfolio size [13]. The relative differences between Tier 1 and Tier 2 patent should be smaller for firms with larger patent portfolios.

Proposition 3. *Technological obsolesce has a differential impact on patenting strategies. The effect is less notable for firms with a larger portfolio.*

4 Welfare implications

To show this theoretically. Assume if the innovator is the only firm in the market, his innovation will generate per-period profit π_0. π_0 could be infinitesimal or huge at beginning depending exogenously on other parameters related to technology characteristics.[14] For simplicity, the there could be two profit levels: $\overline{\pi}$ and $\underline{\pi}$, which reads "pi high" and "pi low", respectively. In addition, I assume there are three periods, so the possible profit chain due to innovation could be any triple combination of there two levels of profit, a total of eight different situations. After three periods, the long patent will expire and the innovation will be competitively supplied. I assume a on time patent to be the patent that start to protect in the first period. A late patent to be a patent that can only protect the second period. Furthermore, I define the breadth of patent to be α which is between 0 and 1. The per-period monopoly profit earned by the innovator is then $\alpha\pi$. So when $\alpha = 1$ the patent is very broad and excludes any other firms from competing with the innovator. $\alpha = 0$ is an extremely narrow patent which is useless. Further, I define the length of patent protection to be the number of periods the patent can protect. I restrict attention to patents that can only protect for either one or two periods as a patent protecting for three periods is not only an on time patent but also the longest patent. I call a one period patent a "short" patent

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[13] Due to the limitation of the data, our empirical findings are not able to include other characteristics at the firm level.

[14] Endogenizing the profit chain essentially will not change the result but only add in more complexity. Specifically, I can assume the profit chain depends on firm's stock of R&D, capital, labor, net work, market environment and technology characteristics. If the technology characteristics can be assumed to have an exogenous component, (e.g. conducting pharmaceutical research is very different as conducting software innovation). Then the overall effect on profit chain can be treated as solely affected by this exogenous variation after taking all the other endogenous effects into consideration. Alternatively, the timing of filing a patent can also be dependent on the underlying profit chain. Specifically, I can assume the innovator can decide a optimal timing of filing patent. The timing of filing can be immediate or long after the timing of innovation depending on how likely the innovator can find a viable way of generating profit from the innovation (notice the innovator can choose the delay of filing to be infinite and this choice corresponds to the protecting IP through secrecy). During the delay, there is also a hazard of getting "business stolen" by other firms if other firms choose to file patent containing overlapping technology features earlier. In fact, in Pharmaceuticals, firms always file patent at the time of innovation rather than commercialization. It is less clear whether the filing behavior in other technology fields follow similar patterns. So the optimal timing again depends on how likely commercialization and imitation can be discovered within a short time, which, of course can then be assumed to contain exogenous components related to technology characteristics.

and a two periods patent "long patent". It is relatively simply to generalize the model to infinite periods by changing the per-period profit into a initial period profit and a exogenous depreciation parameter which depends on the speed of technology follow-up research. It will not add in any further interesting features albeit formation.

So a patent is a triple (i, α, n), where $i = 1, 2$ is the starting period of protection (corresponding to on time or late patent. $n = 1, 2$ is the number of periods protected (corresponding to short or long patent). I compare the ex-post profits secured by applying for two types of patent, one is on time patent but relatively narrow and short, the other is late patent but broader and longer. In short, I assume the two types of patent protections are $(1, \underline{\alpha})$, $(1$ and $2, \overline{\alpha}, 2)$ and $\underline{\alpha} \leq \overline{\alpha}$. Under the current U.S. patent system, the patent application process is significantly delayed by the back log problem. On average, patent application is sitting in que for 2.5 years before emerging on examiner's desk. Further, the resources devoted to examining patents also suffers from significant shortage resulting in a lengthy patent examination. The patent, once granted however, is protected for 20 years. U.S. patent protection is broader than that in most other countries, particularly Japan, partly due to the "doctrine of equivalents," which can broaden protection beyond the claims in the patent according to similarity of function. (See Schotchmer 1991) Motivated by the 1980 establishment of CAFC, the U.S. has also entered into a pro-patent stage. Based on the practical situation, U.S. patent can be regarded as a stronger, however late patent protection. If the late patent is able to generate a certain level of ex-post profit V to the innovator, will it be possible that a narrower shorter but on time patent generate the same ex-post profit? To illustrate this with our simple model, with a late yet strong patent, the aggregate ex-post profit (assuming a discount factor r between periods) is:

$$\Pi_L = \frac{\overline{\alpha}\pi_2}{r} + \frac{\overline{\alpha}\pi_3}{r^2}$$

Although the date of innovation is the first period, since the patent is not effective until the second period, I assume the 1st period profit due to patent is zero. One way to interpret this is that applicant does not have the legal patent right to call for injunction while the patent is still pending. Although if anyone did potentially infringe the innovation under examination, the owner has the right to call for injunction and gain retrospective damage as soon as the patent is granted, the general principle is that the infringed claims have to be substantially the same to make the infringement suit effective. This principle makes calling for retrospective damage very hard to realize. As patent applications are publicized after 18 months of application, a period much earlier than grant decision, potential "business stealing" imitators have sufficient time to avoid being called infringing by changing the product they will sale. Alternatively, the low first period profit can be regarded as a strategy of not commercializing during the pending period due to concerns on fast imitation by reverse engineering. (Examples please!) I can also interpret the innovator not being able to find another another firm that is willing to license its innovation while the patent is still pending, thus delaying the commercialization. similarly with an on time but shorter patent, the aggregate ex-post profit is:

$$\Pi_O = \underline{\alpha}\pi_1$$

where the π_i, $i = 1, 2, 3$ denote the per-period profit due to patent which can be either high type or low type.

It is straight forward to see that the $\Pi_O > \Pi_L$ is most likely to happen is the profit chain is $(\overline{\pi}, \underline{\pi}, \underline{\pi})$, i.e. if the innovation generates high profits in the immediate period after the date of innovation but the profits quickly depreciates away in later periods. Of course, whether $\Pi_O > \Pi_L$ is true will depend generally on the assumptions of the relative sizes of the parameters, which is not interesting. In this case, since $\Pi_O > \Pi_L$, and $\Pi_L \geq V$ I find that $\Pi_O > V$. So a narrower, shorter yet on time patent can still generate sufficient ex-post profit to induce R&D effort. The main focus of this paper is to empirically demonstrate the above situation happens under certain characteristics of technology.

I now show that conditioning on $\Pi_O > \Pi_L$, the on time, weak patent generates more social welfare than the late strong patent. Assume per-period welfare as a function of per-period profit $W(\pi)$ that satisfies $W^{'}() < 0$. With the late but strong patent, the welfare is:

$$\frac{W(\overline{\alpha}\pi_2)}{r} + \frac{W(\overline{\alpha}\pi_3)}{r^2} + \frac{W(0)}{r^3}$$

where $W(0)$ is the welfare when the patent expires and the monopoly profits shrink to zero. With the on time but weak patent, the welfare is:

$$W(\underline{\alpha}\pi_1) + \frac{W(0)}{r} + \frac{W(0)}{r^2} + \frac{W(0)}{r^3}$$

It is straight forward to see that the social welfare in the latter is greater. It is greater with a narrower and shorter patent because narrowing down and cutting the patent periods both reduces per period and number of periods of deadweight loss. Although the on time patent creates distortion the the very beginning period of the innovation, the welfare is still greater since during the same period with the late patent, innovator is less incentives to commercialize their product and that contributes nothing to the enhancement of social welfare. In the very first period, the social value is the difference in consumer's sillinesses to pay for the improved and unimproved products. If an innovation is a reduction in the cost of producing a good, then the social value is the saved costs.

5 Measuring Rate of Technology Obsolescence

The rate of technology obsolescence reflects the idea of how fast new and marginally improving technologies emerges on the market and displaces the current technology. I use patent renewal decisions to create a proxy variable for this concept. This is because when new and superior technology is introduced, the product using the current technology will lose its economic value to the customer; the associated patent will lose its private value to the inventor. So higher rate of technology obsolescence will correspond to shorter effective patent life, expediting the abandonment of patents. More specifically, we aggregate the renewal decisions for patents that are in the same technology areas to proxy for rate of technology obsolescence. Suppose for patent i that is filed in year$t$, denote the technology fields that the patent is located as $(S_1^{it}, S_2^{it}, S_3^{it}, ...S_n^{it})$, where $S_j^{it} = 1$ if patent i is located in technology field j and 0 if not. Define $D_m^{it} = 1$ if patent i is abandoned within m years after grant or 0 otherwise. Suppose there is a total of Q patents that are filed in year t. With these notations, we define the technology level rate of obsolescence for technology j as:

$$STD_{jt} = \frac{\sum_{i=1}^{Q} S_j^{it} \cdot D_m^{it}}{Q}$$

That is, we categorize each patent by its application year and technology. For each cohort-technology category, we use the percentage of the patents that are given up within m years as the proxy variable of the rate of technology obsolescence. The above definition treats each patent as a separate patent in each of its technology fields. Although the speed of technology development should follow similar patterns across the world, each country should have its unique patterns in technological progress due to differences in market development. The measure of rate of technology obsolescence, therefore, should be measured by using patents filed within the same country. Figure 1 shows the rates of technology obsolescence (m=4) in the United States, Germany, France and Great Britain during the periods 1981-2005. For the United States patents, my technology definition follows the USPC 3-digit (741 classes); for the three European countries, my technology definition follows the IPC 4-digit (602 classes). For illustration purpose, I aggregate the patents into six large technology areas as defined in (Hall, Jaffe, and Trajtenberg 2001). The technology fields are Chemical, Computer&Communication, Drugs&Medical, Electrics&Electronics, Mechanics and Others. Since the HJT definition associated each USPC classification into the six technology fields, the categorization of the European patents are made using a USPC-IPC concordance.

First, there is considerable variation in the measure across technology fields. In U.S, for example, the technology field Others has the highest rate of technology obsolescence (18.3%) which is almost twice the measure for Computer and

Communication (9.5%). Second, the rankings of the technology obsolescence measures change over time in all four countries. In France during 1980-1985, the technology field Computer&Communications has the lowest STD_{jt}. It quickly bumped up and surpassed Chemical and Drugs&Medical in the following 5 years. Third, STD_{jt} in different technology fields have similar trends over time. Fourth, there is considerable variation also in the rankings of technology fields in different countries, indicating different countries have different technology development.

Table 1 illustrates the changes of STD_{jt} over the period 2000-2005. The technology areas that have the largest decreases in the rate of technology obsolescence are Leather Manufacturing, Musical Instruments. The technologies which have the highest increase in developments are Bath, Closets, Sink, Package and Games. The fields that remain relatively stables include X-ray, Drug, Organic compounds. It is interesting to notice that the most volatile changes in STD_{jt} locates in technologies that focus on the development of shape, structure or function of products while the STD_{jt} remains unchanged for basic and applied research. Similar tables for the European countries are included in the appendix.

Since the model relates technology obsolescence with individual patent choice and each patent can belong to more than one technology field, we further define for each patent i filed in year t, the mean rate of technology obsolescence as:

$$MeanSTD_{ijt} = \sum_{j=1}^{n} S_j^{it} \cdot STD_{jt}$$

that is, the mean rate of technology obsolescence is a summation of the technology obsolescences weighted by the patent's technology areas. In the empirical analysis, I take into account when a patent application is filed, the applicant can only observe the rate of technology obsolescence in previous periods. So for each patent, I further demean the measure by a three year average of $MeanSTD_{ijt}$ in the previous periods of the patent's application date.

Bilir (2013) has proposed to use mean forward citation lag as the measure of the rate of technology obsolescence. While the "citation lag" measure has the advantage that it exploits relative information throughout patents' lifetime, it also has the disadvantage from truncation problem as significant portion of citations appear after 5 years of patent grant (Hall, Jaffe, and Trajtenberg 2001). In addition, citing a previous patent is more consistent with the understanding that the previous patent is "narrowing" the scope of the current patent rather than the innovations protected by the previous patent is invented around by the innovations under the current patent. Conceptually therefore, it seems the "renewal" measure proposed in this research is more closely related with the rate of technology obsolescence. Another advantage of my measure is that I categorize the technology fields at a much smaller cluster. Compared to Bilir's classification at SIC 3-digit level (37 sectors), my measure is at the USPC 3-digit level (741 fields). (What's the benefit? Simply stating this makes the empirical results stronger is a stupid statement) Nevertheless, I also report my regression results based on Bilir's measure using mean citation lag in the appendix.

6 Data description and summary statistics

To empirically evaluate the propositions presented in the theoretical model, I need measures for rate of technological obsolescence, patent informations for innovations filed in China and U.S, China and Europe. I describe the method of creating measures and data selection criteria below.

I combine informations from several datasets: patent data published by SIPO 1985-2012, Patent information from USPTO website, Harvard Patent Dataverse, EPO PATSTAT. The patent dyads can be identified using the "priority number" information from each U.S. and EPO patent and match it to the application number of Chinese patent. Using the "legal status" information in PATSTAT, I further identify all EPO patents that are designated to Germany, France and Great Britain. Harvard Patent Dataverse provides information on U.S. patents. In addition, I also use the USPTO website to extract all the USPC classifications for each U.S. patent. Since Chinese utility model patent can only protect industrial product innovation while invention patent can protect both process and product innovation, it is important to distinguish process and product invention patents. Fortunately, the title of each Chinese patent application needs to follow a strict format. For process innovation, the title needs to contain key words such as "process," "method." For product innovation, the key words are "product," "structure".

Table 3 provides summary statistics of SIPO-USPTO patent dyad dataset for all variables used in regressions. 23% of the sample were filed utility model in China. Up to present, 28% of U.S. patent applications are granted while the rest are either rejected or still under examination. The grant rates for the U.S. patent application with Chinese invention patent and utility model priorities are 28.86% and 27.75%, respectively (the difference in grant rates is statistically insignificant). There are a total of 4,652 U.S. patent applications with Chinese invention patent priority of which, 1,424 (30.61%) are product innovations, 901 (19.37%) are process innovations and 2,327 (50.02%) are both product and process innovations. There are 1,556 U.S. patent applications with utility model priority and all of them are product innovations. There are a total of 1155 distinct assignees. There are 368 assignees that have never filed any other invention patent prior to the one in our sample. On the other side, only 21 assignees have a invention patent portfolio larger than 50 prior to the patent they filed both in China and U.S, with the largest assignee having 1681 invention patents.

Figure 2 shows the differences in the grant lag between Chinese invention patent and Utility Model patent from 1985 to 2012. On average, invention patent is granted 1621 days after application while utility model is only 434 days after application. Table 1 shows the percentage of invention patent and utility model in the six broad technology fields as defined in HJT. The percentage of Chinese utility model patents varies significantly across different technologies. In Electrics & Electronics, Mechanicals and Others, the percentage of U.S. patents with Chinese utility model priority ranges from 40 % to 60 %. In contrast, in Chemicals, Computer & Communication, Drugs & Medicals, less than 15 % inventions were filed under utility model. Clearly shown, the choice of IP protection varies across technology areas.

Two limitations of the datasets need to be addressed. As mentioned above, one of the advantages of Chinese utility model is the relative low cost of application and maintenance. Interviews with law firms reveal the application cost is largely consist of hiring lawyers in preparation of patent application. For example, one lawyer from Tee&Howe, a intellectual property attorney in Hong Kong told us they charge 220 rmb ($34) per 100 Chinese character in the year 2013. It seems the closest proxy variable for the lawyer cost is the number of words appear in each application document. One disadvantage of SIPO patent dataset is that it does not contain full information for the contents of patent application[15]. Google transforms the original Chinese patent application pdf file into an online html format that is able to be extracted. Thus we are able to acquire the total number of (both independent and dependent) claims for each Chinese patent application. Unfortunately, the html webpages also contain many other contents of patent, so a simply word count of the entire file does not give us the exact amount of words in the patent application.

The second limitation is we are unable to find a good dataset that provides firm financial data. Similar to COMPUSTAT, the National Bureau of Statistics (NBS) in China also provides financial data for Chinese companies that have annual sale above five million rmb. Matching the NBS data with our patent dyads will drop almost 70% of our patent observations

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[15] The SIPO patent dataset in the CD-ROM only provides one independent claim per patent. The full contents of each patent can be retrieved in a PDF file on SIPO website.

since most patent dyads are not filed by large firms. For this reason, we decide not to incorporate the firm level data into our analysis. In our analysis, we control for only one firm level variable, the size of patent portfolio prior to the patent application.

The patent dyads (both SIPO-USPTO and SIPO-EPO) contain Chinese patents whose application year is between 2001-2006. Although in China, there is no specific legal changes with respect to the terms and enforcement for invention patents and utility models during 1993 and 2008 as codified in Chinese patent law[16], the 6-year span of data is arguably the longest time period we can use to test our theoretical model. In U.S, foreign patent application information becomes available only after the AIPA (American Inventor's Protection Act) in 1999. The reduced form approach requires the rate of technology obsolescence to be at least 1 period prior to the Chinese patent application date, effectively pushing the starting period of patent application two periods after 1999. In addition, patent renewal decisions suffer from increasing truncation problem as the application date becomes closer to present. The patent grant lag in the United States is normally longer than 3 years. The patent renewal schedule at USPTO requires patentees to submit patent renewal fees after 3.5 years, 7.5 years and 11.5 years from patent grant. So in order to observe a U.S. patent to be renewed once by 2013, it will require the patent to be applied at least 6 years ago. So 2006 is selected as the last period.

7 Econometric model

The invention patent corresponds to the Tier 1 patent while the utility model corresponds to the Tier 2 patent. *Proposition* 1 states that when the rate of technology obsolescence increases, patent applicants will find utility model more favorable. This result motivates an estimating equation of the following form:

$$D(UM_{ijkt}) = \beta + \beta_1 \cdot MeanSTD_{ijt} + \Gamma \cdot X_i + \theta_t + \eta_j + \lambda_k + \epsilon_{ijkt} \tag{8}$$

where $D(UM_{ijkt})$ is a dummy variable that equals one if the applicant has chosen utility model in China for patent i of firm k in technology field j, during year t. *MeanSTD*$_{ijt}$ is defined as the average percentage of patents that are given up within four years from issue date for all (either U.S. or European) patents that are filed in the past three years and in the same technology fields (USPC 3-digit or IPC 4-digit) as the observed patent. X_i is the control variables at patent and firm level. As explained above, the inventions filed under utility model might have significantly lower technical quality compared to those under invention patent since no examination is required. To control for this issue, I add in a control variable *Grant* which measures whether the U.S. or EPO patent is granted eventually. Although the grant decisions happen at a later time compared to the application date, it is exogenous to the applicant. Therefore, I use this *ex post* decision as a proxy variable of the invention's technical quality which is *ex ante*. Even if the U.S or EPO grant rates for invention patent and utility model are similar, it remains difficult to discern the relative quality between the two groups. To solve this problem, I add in patent level variables at application date to further control for patent quality variations. Consistent with the previous literature, these controls include number of patent claims, number of inventors (Chinese and foreign inventors are treated equally), number of assignees (Lanjouw and Schankerman 2004). Previous literature has pointed out that number of countries applied is positively correlated with the quality of patent (Putnam 1997). Since our data already includes patents that are filed in at least two countries (and mostly two to three patent offices), we do not explicitly control for this. In addition, international patent filing can be processed through either directly filing in the designated

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[16] As mentioned earlier, the Chinese patent law was amended three times and the second amendment, which took place in 2000, did not specifically change the term or enforcement of either invention patent or utility model. It should be noted that when judging an infringement case, the judges will also take into consideration of "several provisions of the Supreme People's Court on Issues Concerning Applicable Laws to the Trial of Patent Controversies.

country(s) or PCT (Patent Cooperation Treaty) route. Since different route might reflect applicants' heterogeneous motives of patenting, it is important to control for this variable. To partially account for strategic motives of patenting, we control for one important firm characteristic (and the only one), the size of the patent portfolio prior to the application date of the observation. Strategic patenting is found to be mostly common in the group of "experienced patent filers" (Kortum and Lerner 1998) and R&D intensive firms (Hall and Ziedonis 2001). Our data limits our identification due to the relative scarce financial information on Chinese innovation firms[17]. Legal conflicts related to patents are mediated at the province level; we therefore control for the geographic location of the patent applicants.

The main coefficient of interest β_1 captures the influence of technology obsolescence on patenting behavior. According to the model, $\beta_1 > 0$ indicating in faster developing technology fields, applicants should have higher propensity of selecting Utility Model patents.

The specification above includes a number of controls. Technology field fixed effects η_j absorb omitted technology fields characteristics such as the extent of complexity of innovation, the cumulative vs. independent nature of technology progress, the ease of reverse-engineering, the preference for choosing patents as a means to protect intellectual property and total technology R&D size and also $MeanSTD_{ijt}$. The year fixed effects θ_t captures for time varying characteristics that affect patenting choices, including technology opportunities, changes in R&D and patenting costs as well as $MeanSTD_{ijt}$. The firm fixed effects λ_k control for unobservable firm characteristics that are invariant over time.The error term ϵ_{ijt} combines any omitted factors that affect applicant's patent choice decisions. Since patenting strategies could be correlated within same technology, I cluster the standard errors at patent's main technology classification.

Proposition 2 states that the impact of technology obsolescence on patent choice is also affected by how fast SIPO processes invention patent. If applicants expect the invention patent to be processed faster at SIPO, the advantage of filing for Utility Model will be diminished. Empirically, we examine this hypothesis as follow:

$$D(UM_{ijkt}) = \beta + \beta_1 \cdot MeanSTD_{ijt} + \beta_2 \cdot MeanSTD_{ijt} \cdot MeanGrantlag_{ijt} + \Gamma \cdot X_i + \theta_t + \eta_j + \lambda_k + \epsilon_{ijkt} \tag{9}$$

where the new variable $MeanGrantLag_{jt}$ is the cohort-technology level average grant lag of standard patent examination delay in the past 3 years before the patent application in China. $MeanGrantlag_{ijt}$ is a sum of average invention patent grant lags in technology j weighted by the technology presences of patent i. Smaller $MeanGrantLag_{jt}$ indicates a higher speed of standard patent examination and a reduced advantage associated with Utility Model Patent. According to the model, applicants should be less sensitive to technology obsolescence changes for smaller $MeanGrantLag_{jt}$ compared to larger $MeanGrantLag_{jt}$. This corresponds to $\beta_2 > 0$.

Proposition 3 states that applicants' heterogeneity of patent portfolio size affects their patent choice responses to changes in technology obsolescence. Applicants with larger patent portfolios is less sensitive to changes in technology obsolescence because he can utilize the advantage of his patent stock to partially overcome the relative inefficiencies due to the slow speed of invention patent or the low enforcement strength and the short protection term of the utility model. Empirically, we estimate the following specification:

$$D(UM_{ijkt}) = \beta + \beta_1 \cdot MeanSTD_{ijt} + \beta_3 \cdot MeanSTD_{ijt} \cdot Portfolio_{kt-1} + \Gamma \cdot X_i + \theta_t + \eta_j + \lambda_k + \epsilon_{ijkt} \tag{10}$$

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[17] The Chinese NBS (National Bureau of Statistics) has provided financial data at firm level for firms with annual revenue over five million yuan (approximately 820 thousand dollars). However, matching the NBS data with the SIPO-USPTO and SIPO-EPO patent data will shrink the sample size to less than one third.

where $Portfolio_{kt-1}$ is the size of patent portfolio (both invention patent and utility model) in firm k in period $t-1$. *Proposition* 3 corresponds to $\beta_3 < 0$.

8 Identification

Identification of β_1 is based on within-technology variation of the rates of technology obsolescence. A key advantage of this approach is that it mitigates concerns of comparing patenting behaviors in different technology fields. As discussed extensively in the literature, the effectiveness of patents varies significantly in different industry sectors. Patents have been perceived to be most effective in Pharmaceuticals; its effectiveness diminishes in other technology areas, noticeably Electrics and Electronics. Since such factors can affect applicant's patenting strategies, the interpretation of β_1 in a regression without controlling for technology fixed effects will be unclear.

As pointed out by the literature, changes in patent behavior in different technology fields can be decomposed into two effects: changes in the composition of firms in the technology over time (entry and exit) and changes in the economic behavior of existing firms (Hall and Ziedonis 2001). To address this concern, we compare estimates of β_1 obtained from regressions with both technology and firm fixed effects with regression only including technology fixed effects. (Need to ask Michael, Max, Sofia for more instructions).

Although we are primarily interested in applicant's patenting behaviors in China, we specifically choose our measure of technology obsolescence to be calculated based on patents in a foreign patent office. A key advantage of this approach is that it avoids empirical ambiguity of simultaneous country level technology opportunities. If new research opportunities arise exogenously in a given technology field, then all applicants in that area will conduct more R&D and may change their patenting choice decisions, an effect that may be erroneously picked up by the $MeanSTD_{ijt}$ measure if it were calculated using SIPO patent information. In contrast, we use foreign patents to calculate the $MeanSTD_{ijt}$ so that β_1 will have a clear interpretation. This is because variation in $MeanSTD_{ijt}$ determines applicant's patenting choice decisions, while technology opportunities are theoretically independent across countries. $MeanSTD_{ijt}$ thus allow us to capture the effect of universal technology obsolescence separately from country-specific technology opportunities even if both are happening simultaneously.

9 Main Results

9.1 Rate of Technology Obsolescence and Patenting Choice

Corresponding estimates of (8) appear in the Table 5. The results are strongly consistent with *Proposition* 1 in the theoretical model. In column 1, I find evidence that in technology fields with higher rates of technology obsolescence? higher $MeanSTD_{ijt}$? patent applicants have a higher propensity to choose utility model to protect their innovation. In addition, whether the U.S. patent application is eventually granted (as measured by the dummy variable *Grant*) is not significantly correlated with applicant's patenting choice. This result supports the validity of our sample selection criteria that the *ex ante* technical qualities of the inventions are not systematically differentiated between the Chinese invention patent and utility model groups. In column 2, I add in patent level variables to further control for potential patent quality differences and find that the influence of rate of technology obsolescence remains nearly identical. The point estimates o β_1 (6.0868 in column 1 and 5.9870 in column 2) corresponds to a marginal effect of 133% increase in the propensity of filing utility model (calculated using results from column 2). More specifically, given the technology field fixed, if there is a 5% increase in the number of patents that are abandoned within 4 years after grant, there will be 7.6% increase in the propensity to file utility models in the coming year. In column 3, I add in assignee dummies to screen out patent applicants that have filed only once in the period 2001-2006, dropping more than half the sample. In this case, the point estimates can be interpreted as the effect of technology obsolescence on patent choices at the assignee level. Comparing point estimates in column 2 and 3, I find the one in column 3 to be 80% larger. The increase in the point estimate of β_1 after controlling for assignee dummies shows that the influence of technology obsolescence is not mainly driven by entry of new assignees but rather by changes of economic behaviors of existing assignees. Columns 4-6 replicate columns 1-3 but restrict the sample to include only granted U.S. patents. Compared to 1-3, the results are larger and highly significant. This indicates that the U.S. grant rates for patent applications with Chinese utility model priority is positively correlated with the rate of technology obsolescence. One potential reason is the U.S. applicants are systematically more aggressively pursuing patent right in long-cycle technology fields through filing continuing patent applications. Our results are consistent with this explanation. The point estimates of the variable *Continuation Dummy* is larger in column 5-6 compared to 2-3, indicating the sample of granted U.S. patent has larger portion of continuing patent applications than the sample of U.S. patent application. In our Robustness check, we also same empirical regressions using SIPO-EPO patent dyads. Since European Patent Office does not offer continuing patent application, we should find similar point estimates between columns 5-6 to columns 2-3 in the regressions with European sample. Indeed, we find the results to be consistent with the above explanation.

Although all results are estimated using probit model, the results are consistent under logit and OLS estimations.

9.2 Heterogeneity: SIPO Administration Dynamics

Table 6 provides estimates corresponding to *Proposition* 2. From a PTO's perspective, this panel is of interest because it is related to how effectiveness is the conventional patent as the PTO's examination efficiency changes (e.g. changes in workload, number of examiners, number of administration units etc.).

Regression results in Table 6 are consistent with the theoretical model. The significant drop in number of observations (e.g. in column 1, the original sample includes 4712 observations, now only 2582) after controlling from $MeanGrantlag_{ijt}$ is due to the imperfect match between USPC and IPC[18]. Nevertheless, $MeanSTD_{ijt}$ are still significant in columns 1 and 3 and not highly different from results in the previous table. The key variable of interest, $MeanSTD_{ijt} * MeanGrantlag_{ijt}$ (β_2 in (9)) is always positive and significant whether including patent level control or assignee fixed effects. This indicates that patent applicants are more sensitive to changes in rate of technology obsolescence when SIPO's invention patent examination delay is longer. In column (4), the marginal effect of β_1 and β_2 are -11.61 and 0.0077, respectively. At 25^{th} percentile and 75^{th} percentile of $MeanGrantlag_{ijt}$ (1578 days and 1731 days), one standard deviation increase in the rate of technology obsolescence will patent applicants' propensity for filing utility model by 3.0% and 9.4%, respectively. At the mean rate of technology obsolescence (0.1457), one standard deviation increase in the examination delay at SIPO (147 days) will increase the propensity to file for utility model by 16.49%. At SIPO's mean examination delay (1672 days), this estimate correspond to a grant lag elasticity of demand for utility model of 2.82 which is much larger than unity. Given examiner's effort fixed[19], decrease in PTO's examination efficiency has a significant impact on the effectiveness of the invention patent.

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[18] E.g. in U.S. there is a class named G9B after 1980, but there is no corresponding IPC class

[19] Empirically, patent examiner's working effort is negatively correlated with work loads, (please cite Zhen lei and Jun Byoung Oh)

9.3 Strategic Patenting: Applicant's Patent Portfolio Size

To evaluate *Proposition* 3, we investigate the effect of technology obsolescence on patenting choice across applicants with different patent portfolio sizes. The variable *Large Patent Portfolio Dummy* equals 1 for all applicants whose Chinese patent portfolio size exceeds the mean patent portfolio size of the sample (14 patents) prior to the current patent application and 0 otherwise. We estimate (9) for all applicants included and also variants of (9) separately within the groups of large portfolio size applicants and small portfolio size applicants. Assignee fixed effects are included to control for applicant level unobservables that do not change over time. The results show that small portfolio holders are more sensitive to changes in rate of technology obsolescence that big portfolio holders which is consistent with the theoretical model that big portfolio holders are more capable of circumventing the ineffectivenesses of both invention patent and utility models by utilizing his other patents in the pool. In fact, results in columns 1-2 show that large portfolio holders do not respond to changes in technology obsolescence.

9.4 Subsample estimations

To further evaluate the effect of technology obsolescence on optimal patent choice, we estimate specifications that allow the coefficient to vary across different sizes of technology obsolescence. We categorize $MeanSTD_{ijt}$ into ***Small***, ***Medium*** and ***Large*** STD_{ijt} by the sample's 33^{rd} and 67^{th} percentile, defined in dummy variables $Speed_2$ and $Speed_3$. We estimate the following specification:

$$D(UM_{ijkt}) = \beta + \beta_1 \cdot MeanSTD_{ijt} + \sum_{i=2}^{3} \delta_i \cdot MeanSTD_{ijt} * Speed_i + \Gamma \cdot X_i + \theta_t + \eta_j + \epsilon_{ijkt} \tag{11}$$

Table 8 provides regression results for (11). Comparing column 1-3, the applicants' patent choice is significantly influenced by changes in $MeanSTD_{ijt}$ only in the group of small rates of technology obsolescence. As the rate of technology obsolescence increases, not only do the estimated coefficients become smaller but also statistically insignificant. These results offer further supports to our theoretical model: the advantage of fast protection speed is more salient when the rate of technology obsolescence is relatively high.

10 Robustness checks with SIPO-EPO patent dyads

While our theoretical results relate individual applicant's patenting strategies with technology characteristics, we test our hypotheses based on SIPO-USPTO patent dyads and calculate technology obsolescence measures using only United States patent data. As a robustness check, we replicate our regressions using SIPO-EPO patent dyads and calculate three alternative measures of technology obsolescence based on EPO patent data designated to the following three European countries: Germany, France and Great Britain, respectively.

Table 9-11 reports results for model (8) and provide confirmation for *proposition* 1. Estimates in columns 1 to 6 reveal qualitatively similar pattern of sensitivity to technology change compared to columns 1-6 in Table 5. For the SIPO-EPO patent sample, one standard deviation increase in rate of technology obsolescence increases the propensity to file for utility model by 8.28%, 6.76% and 10.04% using the Germany, France and Great Britain EPO patents as technology obsolescence measures, respectively (using the point estimates from column (3) of Table 9-12). Given that the SIPO-USPTO counterpart is 7.04%; the four results are closely comparable with similar significance.

Table 12-14 reports result for *Proposition 2*.

11 Conclusion

In this paper, we provide theoretical and empirical analysis on how applicants' optimal patent choice is influenced by changes in rate of technology obsolescence. In a simple model where inventors rely on patents to secure monopoly profits due to invention, we highlight the importance of speed of patent grant and develop results with regard to tradeoffs between fast but weak and slow but strong patent protections. The model indicates the tradeoff is influenced by changes in rate of technology obsolescence, a measure we create to proxy for the speed of technology development. Applicants' propensity of choosing fast patent increases as the technology develops faster; this response becomes very salient in technology fields that develops especially fast.

We select SIPO-USPTO and SIPO-EPO patent dyads between 2001-2006 to empirically examine our hypotheses. In order to observe patent applicants' demand for speed of protection, we exploit one interesting feature provided by SIPO: it offers both a conventional patent protection, the invention patent, and a weak but fast patent protection, the utility model. To address the concerns of differentiated patent quality between invention patents and utility models, we exploit the uniform examination feature offered both by USPTO and EPO. Thus, our dyads represent innovations with comparable technical quality but different economic values.

Our empirical results are strongly consistent with our theoretical model. In technology fields where the rates of technology obsolescence increases over time, we find subsequent patent applicants' propensity of choosing utility model also increases significantly. Although utility model is inferior to invention patent due to shorter protection periods, interactions between rate of technology obsolescence and SIPO's average grant lag explains the choice between invention patent and utility model is mainly due to whether applicants need fast speed of protection. The results provide evidence that rate of technology obsolescence is a strong determinant of applicants' patenting strategy both at the technology and assignee level, establishing the causal effect of changes in technology development on patenting choice.

Our results find their usefulness in the literature of optimal design of patent policy. Previous literature reaches a consensus that a uniform patent system is unable to satisfy the heterogeneous demands for patent protection. With the patent attributes fixed, the system tends to over-reward some inventor but under-reward others. We suggest there is an additional policy lever that is worth analyzing: patent applicants might differ in their preferences for how fast the patent can be granted. Our findings suggest speed of patent grant is an important consideration; patent applicants might even willing to secure a fast patent right at the expense of protection length and enforcement strength. These comparisons implies a potential welfare enhancement: since weaker patent creates lesser per-period and total periods of distortion and faster protection makes them more effective to applicants, it is welfare enhancing (compared to the current uniform system) to provide fast but weak patent protections in fast-moving technology fields.

Based on this result, we propose two directions for future research. First, will a hybrid patent system that offers flexibility in protection speed, width and term be welfare enhancing? To answer this question, one needs to compare the welfare of a hybrid system to not only the current patent system with a uniform patent policy but also to a counterfactual case where there is a uniform alternative patent policy with different attributes. Second, future research for patent policy should also focus on how a uniform patent system affects R%D incentives in different technology fields. Further quantitative investigation of these possibilities is important to promote the understanding of patent policy and technology development.

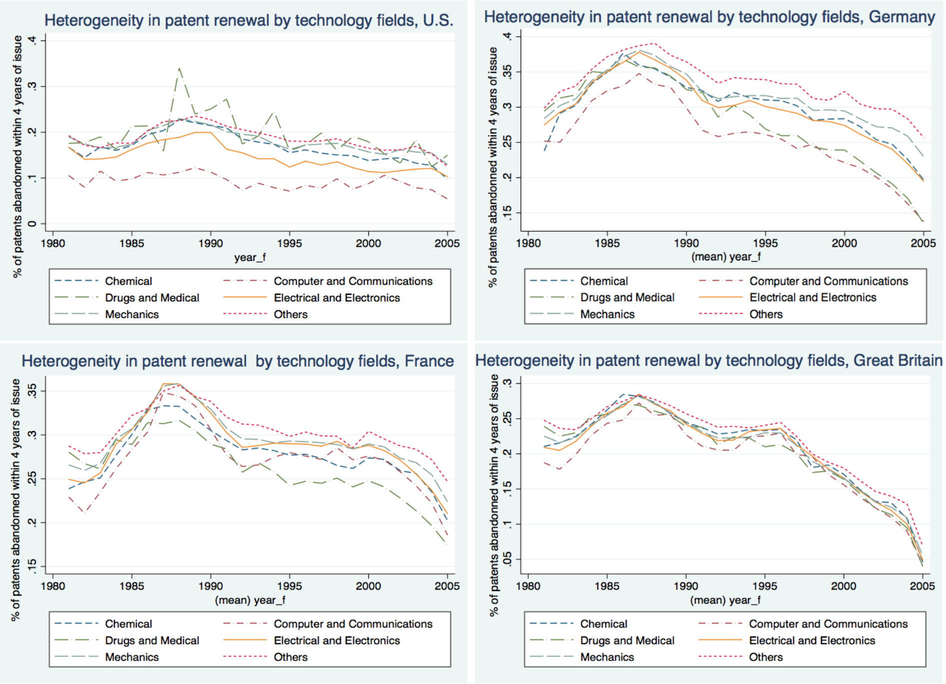

Figure 1: Heterogeneity in Patent Renewal Behaviors by Technology Fields: Germany, France, Great Britain and U.S.

note: 1. Data source USPTO patent dataset and EPO Worldwide Patent Statistical Database April 2011. 2. The technology classification used here is defined in **2001nber** (2001). The definition categorizes patents into 6 big technology fields Chemical, Computer and Communications, Drugs and Medical, Electrical and Electronics, Mechanics and Others based on 3-digit United States Patent Classification (USPC). Since the EPO patents are classified using International Classification Code, we use the IPC-USPC concordance table to transfer IPC into USPC and assign each EPO patent into the HJT patent classification.
note

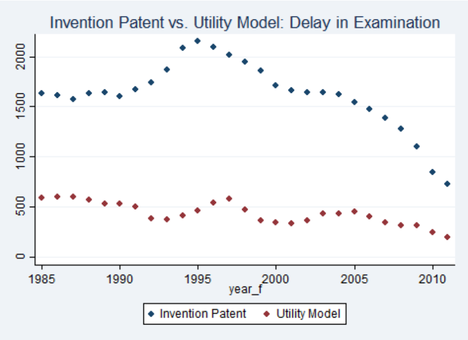

Figure 2: Invention Patent vs. Utility Models: delay in patent grant, 1985-2012

Table 1: Distribution of Chinese Invention Patent and Utility Model Patent by Technology fields

Technology Fields	Invention Patent	Utility Model	% of U
Chemicals	400	66	14.16%
Computer & Communication	1164	97	7.69%
Drugs & Medical	588	54	8.41%
Electrics & Electronics	954	625	39.58%
Mechanicals	342	220	39.15%
Others	390	462	54.23%

Table 2: 2005 cohort rate of technology obsolescence rankings in U.S. by USPC (3-digit)

Technology Fields	Rank	USPC	TFR
Small rate of technology obsolescence			
Scanning Techniques	1	850	1
Musical Instruments	2	984	1
Metal tools and Implement	3	79	1
Amusement Device: Game	4	273	55.55%
Implements for Applying Pushing or Pulling Forces	5	256	51.85%
Medium rate of technology obsolescence			
Selective Cutting	370	234	13.26%
Spring Device	371	267	13.27%
Fluid pressure and Analogous Brake System	372	303	13.28%
Acoustics	373	181	13.34%
Railway Switches and Signals	374	246	13.36%
Large rate of technology obsolescence			
Organic Compounds	737	542	0
Boring or Penetrating Earth	738	175	0
Chemistry: Natural Resin and Derivative	739	530	0
Adhesive Bounding and Miscellaneous Chemical	740	156	0
Needle and Pin Making	741	163	0

Note: Technology classification is based on the 3-digit United States Patent Classification (USPC). There are a total of 741 technology fields. All patents used were flied at USPTO in the fiscal year 2005. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

Table 3: Changes in rate of technology obsolescence 2000-2005, USPC 3-digit

Technology Fields	Rank	USPC	TFR changes
Biggest decrease in rate of technology obsolescence			
Leather Manufacturing	1	69	-39.24%
Musical Instruments	2	984	-27.35%
Horology	3	79	-24.19%
Knots and knot tying	4	273	-23.54%
Distillation	5	201	-13.74%
Smallest change in rate of technology obsolescence			
X-ray or gamma ray system	314	378	-0.01%
Metal Fusion bonding	315	228	-0.01%
Drug, bio affecting and body treating	316	424	0
Organic Compound	317	536	0.05%
Fuel and related composition	318	44	0.08%
Biggest increase in rate of technology obsolescence			
Bath, Closets, Sink, Spittoons	737	4	15.91%
Special Receptacle or Package	738	206	16.66%
Amusement Device: Game	739	273	26.79%
Books, Strips and Leaves for manifolding	740	462	30.78%
Beds	741	5	46.74%

Note: Technology classification is based on the 3-digit United States Patent Classification (USPC). There are a total of 741 technology fields. All patents used were flied at USPTO during the fiscal years 2001- 2005. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

Table 4: Summary Statistics of Regression Variables, SIPO-USPTO patent dyads

Variables	Mean	Standard Deviation	Min	Max
Patent Information:				
Chinese Utility Model Dummy	0.2369	0.4252	0	1
Grant in U.S. Dummy	0.2848	0.4513	0	1
Number of Claims per Patent (USPTO)	15.7604	9.4953	1	158
Number of Inventors per Patent (USPTO)	2.5083	1.4372	1	5
Number of Assignee (Patentee)	1.0451	0.2196	1	4
Continuing Patent Application Dummy	0.0597	0.2369	0	1
PCT Patent Filing Dummy	0.3310	0.4706	0	1
Applicant Type (1 Firm; 0 Non-Firm)	0.6548	0.4754	0	1
Applicant Nationality (1 Domestic; 0 Foreign)	0.8208	0.3834	0	1
Innovation Type (1 Product; 2 Process; 3 Both)	1.8948	0.9186	1	3
Technology Information:				
Rate of Technology Obsolescence	0.1262	0.0547	0.0318	0.3469
Number of Technology fields: 741				
Assignee Information:				
Invention Patent Portfolio Size	14.8011	80.5061	0	1239
Number of Distinct Assignee	1683			
Others: Number of Observations	6565			

Note: Need to change

Table 5: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all USPTO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.322 for all USPTO patent applications. Rates of technology obsolescence are calculated using all USPTO patents applied during 1998-2005)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} (*weighted USPC*)	6.0868	5.9870	10.0669	16.2840	18.0859	13.1274
	(2.2502)***	(2.1294)***	(4.339)***	(5.5076)***	(5.3795)***	(5.7577)***
Grant	-0.1019	-0.018	0.1485			
	(0.8712)	(0.0719)	(0.8676)*			
Patent Portfolio Size		0.001	0.0004		-0.0005	-0.0002
		(0.0004)**	(0.0002)**		(0.0007)	(0.0008)
Number of Claims		-0.0154	-0.1265		-0.0081	-0.0083
		(0.004)***	(0.0092)		(0.0121)	(0.0268)
Number of Inventor		-0.1154	0.007		(-0.0551)	(0.2120)
		(0.0313)***	(0.0078)		(0.0638)	(0.0712)***
Number of Assignee		-1.013	-0.6463		-1.6436	(-0.5627)
		(0.2351)***	(0.4336)		(0.4750)***	(0.5962))
Continuation Dummy		0.1189	-0.0211		0.1845	(0.3120)
		(0.1333)	(0.1801)		(0.2415)	(0.3702)
PCT Filing Dummy		-0.3241	0.0879		-0.4737	0.0642
		(0.0852)	(0.1525)		(0.2269)**	(3374)
Patent Characteristics	No	Yes	Yes	No	No	Yes
Application Year Dummies	Yes	Yes	Yes	No	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	No	Yes	Yes
Assignee Dummies	No	No	Yes	No	Yes	Yes
N	4712	4712	2310	888	888	538
Log PseudoLH	-1944.9714	-1868.3764	-867.6572	-442.9037	-414.9759	-229.1733
Pseudo R^2	0.3437	0.3696	0.4444	0.2557	0.3026	0.3837

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all USPTO (The United States Patent and Trademark Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for USPTO patent applications; column (4)-(6) reports results for USPTO patents. Heterogenous Robust standard errors are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all USPTO patents that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application, whether the patent application is a PCT application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 741 3-digit USPC fields).

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12 Appendix

Proof of lemma 1: when $\rho = 0$,

$$\int_{min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})}^{+\infty} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds = \int_{T_2}^{+\infty} e^{-rs} \cdot (b_1\pi - c)ds$$

Using the condition from the *Lemma*, we see that:

$$\int_{T_2}^{+\infty} e^{-rs} \cdot (b_1\pi - c)ds \geq \int_{t_2}^{t_1} e^{-rs} \cdot (b_1\pi - c)ds \geq \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi - c)ds$$

Define $K(\rho, T_1) = \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi \cdot e^{-\rho s} - c)ds - \int_{T_2}^{T_1} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds$. We have just shown that $K(0, +\infty) < 0$. Moreover, $K(0, T_1)$ is strictly increasing in ρ at $(0, +\infty)$:

$$\begin{aligned} \frac{dK(\rho, T_1)}{d\rho}|_{(0,+\infty)} &= -\int_{t_1}^{t_2} se^{-rs}(b_2\pi - c)ds + \int_{T_2}^{+\infty} se^{-rs}(b_1\pi - c)ds \\ &> -\int_{t_1}^{t_2} t_2 e^{-rs}(b_1\pi - c)ds + \int_{T_2}^{+\infty} T_2 e^{-rs}(b_1\pi - c)ds > 0 \end{aligned}$$

where the last inequality follows from the regularity condition. Since $K(0, +\infty) < 0$, there exists sufficiently small ρ such that $K(\rho, +\infty) < 0$ (although $K(\rho, \infty) > K(0, \infty)$). $K(\rho, T_1)$ is decreasing in T_1. Since $K(\rho, +\infty) < 0$, there exist sufficiently large T_1 such that $K(\rho, T_1) < 0$. We can always choose T_1 and ρ such that $T_1 \leq \frac{1}{\rho} \cdot log\frac{b_1\pi}{c}$ hold. Therefore, $T_1 = min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c})$. Since T_2 is fixed, for sufficiently large ρ, it must be true that $T_2 = min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})$. So

$$\begin{aligned} & K(\rho, T_1) < 0 \\ \Leftrightarrow \quad & \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi \cdot e^{-\rho s} - c)ds - \int_{T_2}^{T_1} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds < 0 \\ \Leftrightarrow \quad & \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi \cdot e^{-\rho s} - c)ds - \int_{min(T_2, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})}^{min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c})} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds < 0 \end{aligned}$$

It is straightforward to see that $\Pi_2 - \Pi_1$ is smaller than the last inequality so the conditions on t_1, t_2, T_2 are sufficient but not necessary.

Proof of Proposition 1: Since the integral interval points are determined by the minimum of two variables, the best way to illustrate the first order derivatives is to discuss under separate cases. Suppose ρ and T_1 and T_2 satisfies $\frac{1}{\rho} \cdot log\frac{b_1\pi}{c} = min(T_1, \frac{1}{\rho} \cdot log\frac{b_1\pi}{c})$ and $\frac{1}{\rho} \cdot log\frac{b_2\pi}{c} = min(T_1, \frac{1}{\rho} \cdot log\frac{b_2\pi}{c})$. In addition, assume $t_1 < \frac{1}{\rho} \cdot log\frac{b_2\pi}{c}$ so that the 2nd integral exists. In this case, taking the first order derivative w.r.t. $\Pi_2 = \Pi_1$

$$\begin{aligned} \frac{d(\Pi_2 - \Pi_1)}{d\rho} &= -\int_{t_2}^{t_1} se^{-(r+\rho)s} b_2\pi ds + \int_{t_1}^{\frac{1}{\rho}log\frac{b_2\pi}{c}} se^{-(r+\rho)s}(b_1 - b_2)\pi ds + \int_{\frac{1}{\rho}log\frac{b_2\pi}{c}}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} se^{-(r+\rho)s} b_1\pi ds \\ &+ \frac{1}{\rho^2}log\frac{b_2\pi}{c}(\frac{b_2\pi}{c})^{-\frac{r}{\rho}}\frac{b_1 - b_2}{b_2}c + \frac{1}{\rho^2}log\frac{b_1\pi}{c}(\frac{b_1\pi}{c})^{-\frac{r}{\rho}}(\frac{b_1}{b_1}c - c) - \frac{1}{\rho^2}log\frac{b_2\pi}{c}(\frac{b_2\pi}{c})^{-\frac{r}{\rho}}(\frac{b_1}{b_2}c - c) \\ &> -\int_{t_2}^{t_1} t_1 e^{-(r+\rho)s} b_1\pi ds + \int_{t_1}^{\frac{1}{\rho}log\frac{b_2\pi}{c}} t_1 e^{-(r+\rho)s}(b_1 - b_2)\pi ds + \int_{\frac{1}{\rho}log\frac{b_2\pi}{c}}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} t_1 e^{-(r+\rho)s} b_1\pi ds \\ &= b_1\pi t_1 \cdot (e^{-\frac{r+\rho}{\rho} \cdot log\frac{b_2\pi}{c}} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho} \cdot log\frac{b_1\pi}{c}}) \\ &> b_1\pi t_1 \cdot (\frac{b_2\pi}{c}^{-(\frac{rt_1}{logb_1\pi - logc})+1} - \frac{b_1\pi}{c}^{-(\frac{rt_1}{logb_1\pi - c})+1} + e^{-(rt_1 + logb_1\pi - logc)} - e^{-(rt_2 + \frac{t_2}{T_1}(logb_1\pi - logc))}) > 0 > 0 \end{aligned}$$

where the first inequality utilize the facts that $b_1 > b_2$, $t_1 < \frac{1}{\rho} log \frac{b_2 \pi}{c}$ and the second line in the first order condition cancels out completely. Calculating the integrals in the third line gives us the fourth line. Since $\frac{1}{t_1} log \frac{b_1 \pi}{c} > \rho > \frac{1}{T_1} log \frac{b_1 \pi}{c}$, shrinking the positive terms in the above parenthesis to the lower bound and enlarging the negative terms to the upper bound we have the second inequality.

Using this most complicated case as the bench mark, suppose ρ decreases such that $T_2 < \frac{1}{\rho} log \frac{b_2 \pi}{c}$ but $T_1 > \frac{1}{\rho} log \frac{b_1 \pi}{c}$, there is only one integral bound that involves ρ, the first order condition thus becomes:

$$
\begin{aligned}
\frac{d(\Pi_2 - \Pi_1)}{d\rho} &= -\int_{t_2}^{t_1} se^{-(r+\rho)s} b_2 \pi ds + \int_{t_1}^{T_2} se^{-(r+\rho)s} (b_1 - b_2) \pi ds + \int_{T_2}^{\frac{1}{\rho} log \frac{b_1 \pi}{c}} se^{-(r+\rho)s} b_1 \pi ds \\
&+ \frac{1}{\rho^2} log \frac{b_1 \pi}{c} (\frac{b_1 \pi}{c})^{-\frac{r}{\rho}} (\frac{b_1}{b_1} c - c) \\
&> -\int_{t_2}^{t_1} t_1 e^{-(r+\rho)s} b_1 \pi ds + \int_{t_1}^{T_2} t_1 e^{-(r+\rho)s} (b_1 - b_2) \pi ds + \int_{T_2}^{\frac{1}{\rho} log \frac{b_1 \pi}{c}} t_1 e^{-(r+\rho)s} b_1 \pi ds \\
&= b_1 \pi t_1 \cdot (e^{-(r+\rho)T_2} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho} \cdot log \frac{b_1 \pi}{c}}) \\
&> b_1 \pi t_1 \cdot (e^{-\frac{r+\rho}{\rho} \cdot log \frac{b_2 \pi}{c}} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho} \cdot log \frac{b_1 \pi}{c}}) \\
&> b_1 \pi t_1 \cdot (\frac{b_2 \pi}{c}^{-(\frac{rt_1}{log b_1 \pi - log c}) + 1} - \frac{b_1 \pi}{c}^{-(\frac{rt_1}{log b_1 \pi - c}) + 1} + e^{-(rt_1 + log b_1 \pi - log c)} - e^{-(rt_2 + \frac{t_2}{T_1}(log b_1 \pi - log c))}) > 0 > 0
\end{aligned}
$$

where the second inequality follows since $T_2 < \frac{1}{\rho} log \frac{b_2 \pi}{c}$ and the rest of the derivation is identical to the above.

Suppose ρ continue to decrease and $T_1 < \frac{1}{\rho} log \frac{b_1 \pi}{c}$, no integral bound involves ρ so the first order condition will be:

$$
\begin{aligned}
\frac{d(\Pi_2 - \Pi_1)}{d\rho} &= -\int_{t_2}^{t_1} se^{-(r+\rho)s} b_2 \pi ds + \int_{t_1}^{T_2} se^{-(r+\rho)s} (b_1 - b_2) \pi ds + \int_{T_2}^{T_1} se^{-(r+\rho)s} b_1 \pi ds \\
&> -\int_{t_2}^{t_1} t_1 e^{-(r+\rho)s} b_2 \pi ds + \int_{t_1}^{T_2} t_1 e^{-(r+\rho)s} (b_1 - b_2) \pi ds + \int_{T_2}^{T_1} t_1 e^{-(r+\rho)s} b_1 \pi ds \\
&= t_1((\Pi_1 - \Pi_2) + \frac{1}{r}(e^{-rT_2} - e^{-rT_1} - e^{-rt_2} + e^{-rt_1}) \\
&= t_1 \cdot ((\Pi_1 - \Pi_2) - \frac{1}{r} K(0, T_1)) > 0
\end{aligned}
$$

the sat step uses the assumption that $\Pi_1 - \Pi_2 > 0$ and the regularity condition from $Lemma$ 1.

It ρ is big enough such that $t_1 > \frac{1}{\rho} log \frac{b_2 \pi}{c}$ and $t_2 < \frac{1}{\rho} log \frac{b_2 \pi}{c}$,

$$
\Pi_2 - \Pi_1 = \int_{t_2}^{\frac{1}{\rho} log \frac{b_2 \pi}{c}} e^{-rs} (b_2 \pi \cdot e^{-\rho s} - c) ds > 0
$$

So Tier 2 patent is more favorable. The $Lemma$ demonstrates a case where $\Pi_2 - \Pi_1 < 0$ Since $\Pi_2 - \Pi_1$ is a continuous function of ρ, there exists a ρ_* such that $\Pi_2 - \Pi_1|_{\rho_*} = 0$. If ρ_* satisfies $\frac{1}{\rho_*} log \frac{b_1 \pi}{c} < T_1$ and $\frac{1}{\rho_*} log \frac{b_2 \pi}{c} > t_1$, since $\Pi_2 - \Pi_1$ is increasing in ρ for all ρ in interval $(\frac{1}{T_1} log \frac{b_1 \pi}{c}, \frac{1}{t_1} log \frac{b_2 \pi}{c})$, for all $\rho > \rho_*$, $\Pi_2 - \Pi_1 > 0$ holds. If ρ_* satisfies $\frac{1}{\rho_*} log \frac{b_1 \pi}{c} > T_1$, pick ρ_* to be the largest ρ that satisfies this condition. For all $\rho > \rho_*$, $\Pi_2 - \Pi_1 > 0$ holds.

The remain trivial case occurs when ρ is so big that $t_2 > \frac{1}{\rho} log \frac{b_2 \pi}{c}$, then the applicant will not even file for patent, a situation ruled out by the assumption of model.

Proof of Proposition 2: take the first-order derivative of $\Pi_2 - \Pi_1$ w.r.t. t_1:

$$\begin{aligned}\frac{d(\Pi_2 - \Pi_1)}{dt_1} &= e^{-rt_1}(e^{-\rho t_1}b_2\pi - c) + e^{-rt_1}(e^{-\rho t_1}(b_1 - b_2)\pi) \\ &= e^{-rt_1}(e^{-\rho t_1}b_1\pi - c) > 0\end{aligned}$$

so $\Pi_2 - \Pi_1$ is an increasing function of t_1. For a given t_1, since $\Pi_2 - \Pi_1|_{\rho_1, t_1} = 0$, we have $\Pi_2 - \Pi_1|_{\rho_1, t_{1'}} > 0$ for $t_{1'} > t_1$. According to $Proposition$ 1, $\Pi_2 - \Pi_1$ is an increasing function of ρ when ρ is in $[\frac{1}{T_1}log\frac{b_1\pi}{c}, \frac{1}{t_1}log\frac{b_2\pi}{c}]$. This means if $\Pi_2 - \Pi_1|_{\rho_{1'}, t_{1'}} = 0$, then it must be true that $\rho_{1'} < \rho_1$. So when t_1 increases to $t_{1'}$, all the ρ that lies in $(\rho_{1'}, \frac{1}{t_1}log\frac{b_2\pi}{c}]$ will make $\Pi_2 - \Pi_1 > 0$, enlarging the range of ρ applicants that will make Tier 2 patent more favorable.

Changes in China's patent policy 1985-2009.

s a pre-requisite knowledge, I briefly review the important amendments of the Chinese patent policy and compares the relative effectiveness of Tier 1 patent and Tier 2 patent in China. Understanding the designs and changes of the patent policy is the key to data selection and econometric analysis.

The Chinese patent law was enacted in 1984 and put into practice in 1985. The law offers three types of patent protection: the invention patent (Tier 1) which protects industrial process and product innovations; the utility model patent (Tier 2) which protects industrial product innovations and the external design patent, which protects industrial designs.

Since the establishment of the State Intellectual Patent Office (SIPO), serious effort has been made in an attempt to "vitalize the enthusiasm of the scientific and technical personnel and the masses of workers for inventions and creations and to attract foreign firms to China to make investment and transfer technology."(Hill and Evans 1993) As a result, the Chinese patent law has gone through three major amendments in 1992, 2000 and 2008, respectively. The 1992 amendment extends the protection periods of Tier 1 patent from 15 years to 20 years and that of the Tier 2 patent from 7 years to 10 years. In addition, pharmaceutical and chemical inventions, food, beverages and flavoring, previously exempted from patent protection, became patentable subject matters. In 2000, reforms on patent law eliminates the restriction that stated-owned firms cannot trade patent rights on the market for technology. This reform also enhanced the rewards for employees when they successfully patent their innovation. The 2009 amendment enhances the patentability standard. It also strengthened the patent right by increasing the infringement royalty significantly. (Please see appendix for more details).

Note: Technology classification is based on the 4-digit International Patent Classification (IPC). There are a total of 608 technology fields. All patents used were flied at EPO in the fiscal year 2005 and designated to Germany. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

Note: Technology classification is based on the 4-digit International Patent Classification (USPC). There are a total of 608 technology fields. All patents used were flied at EPO during the fiscal years 2001- 2005 and designated to Germany. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

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Note: Technology classification is based on the 4-digit International Patent Classification (IPC). There are a total of 608 technology fields. All patents used were flied at EPO in the fiscal year 2005 and designated to Great Britain. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

Note: Technology classification is based on the 4-digit International Patent Classification (USPC). There are a total of 608 technology fields. All patents used were flied at EPO during the fiscal years 2001- 2005 and designated to Great Britain. TFR is our measure of technology obsolescence. It is defined as the percentage of patents (filed in the same field) abandoned within 4 years after grant.

Table 6: Estimates of Technology Conditions and SIPO patent prosecution lags on Choice of Chinese Patent Protection for all USPTO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.322 for all USPTO patent applications. Rates of technology obsolescence are calculated using all USPTO patents applied during 1998-2005)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} (*weighted USPC*)	4.2885	-48.2041	5.2669	-51.1986	-4.8496	-150.6912
	(2.3474)*	(25.0674)***	(2.337)**	(24.7140)**	(6.3571)	(67.1555)**
Mean $Grantlag_{ijt}$	-0.0004	-0.0045	0.0001	-0.0042	-0.0005	-0.0111
	(0.0007)	(0.0021)**	(0.0007)	(0.0020)**	(0.0017)	(0.0043)**
Mean STD_{ijt} * *Mean* $Grantlag_{ijt}$		0.0318		0.0342		0.0886
		(0.0152)**		(0.0150)**		(0.0407)**
Grant	-0.0796	-0.0728	-0.018	0.0113	0.1472	0.1532
	(0.0741)	(0.0996)	(0.0719)	(0.0973)	(0.1326)	(0.1573)
Patent Portfolio Size			0.0010	0.0012	0.0006	0.0005
			(0.0004)**	(0.0005)**	(0.0006)	(0.0006)
Number of Claims			-0.0154	-0.0164	0.0108	-0.0098
			(0.004)***	(0.0052)**	(0.0103)	(0.0119)
Number of Inventor			-0.1154	-0.1335	-0.0267	-0.0295
			(0.0313)***	(0.0318)***	(0.5031)	(0.0585)
Number of Assignee			-1.013	-1.031	-0.3721	-0.3210
			(0.2351)***	(0.3021)***	(0.4359)	(0.3805)
Continuation Dummy			0.1189	-0.0211	-0.1484	-0.1485
			(0.1333)	(0.1801)	(0.2177)	(0.3091)
PCT Filing Dummy			-0.3241	-0.2418	0.0706	0.0676
			(0.0852)	(0.1650)	(0.1998)	(0.2409)
Patent Characteristics	No	No	Yes	Yes	Yes	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Assignee Dummies	No	No	No	No	Yes	Yes
N	2582	2582	2582	2582	1039	1039
Log PseudoLH	-1092.7957	-1868.3764	-1046.5578	-1042.938	-356.3515	-352.1904
Pseudo R^2	0.3715	0.3733	0.3696	0.4001	0.5023	0.5081

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all USPTO (The United States Patent and Trademark Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for USPTO patent applications; column (4)-(6) reports results for USPTO patents. Heterogenous Robust standard errors are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all USPTO patents that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application, whether the patent application is a PCT application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 741 3-digit USPC fields).

Table 7: Estimates of Technology Conditions and applicants' patent portfolio size on Choice of Chinese Patent Protection for all USPTO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.322 for all USPTO patent applications. Rates of technology obsolescence are calculated using all USPTO patents applied during 1998-2005)

Dependent Variable:	Patenting choice					
	Patent Portfolio Size					
	Large (1)	Large (2)	Small (3)	Small (4)	All (5)	All (6)
Mean STD_{ijt} (*weighted USPC*)	2.9233	7.1284	7.2000	13.0911	6.1434	10.8983
	(4.7990)	(7.7163)	(2.1284)***	(4.440)***	(2.1449)***	(4.4943)**
Large Patent Portfolio Dummy					0.5691	0.7207
					(0.2611)**	(0.3738)*
Mean STD_{ijt} * Large Patent Portfolio					-3.1515	-5.2951
					(1.7821)*	(2.5957)**
Grant	-0.0909	0.2334	0.0261	0.1575	-0.2052	0.1509
	(0.2317)	(0.2122)	(0.0685)	(0.0912)	(0.0714)	(0.0871)*
Patent Portfolio Size	0.0006	0.0004	0.1537	-0.1244	0.0008	0.0003
	(0.0005)	(0.0003)	(0.0576)***	(0.0534)**	(0.0005)	(0.0003)
Number of Claims	0.0318	0.0327	-0.0155	-0.0172	-0.0155	-0.0132
	(0.0199)	(0.0349)	(0.0038)***	(0.0091)*	(0.0039)***	(0.0091)
Number of Inventor	0.1121	0.1543	-0.1315	-0.0094	-0.1153	-0.0112
	(0.0676)	(0.0999)	(0.0287)***	(0.0497)	(0.0315)***	(0.0394)
Number of Assignee			-0.8276	-0.5187	-1.0168	-0.6565
			(0.2247)***	(0.3962)	(0.2373)***	(0.4273)
Continuation Dummy		0.2780	0.0993	-0.0104	-0.1240	-0.0140
		(0.4703)	(0.1538)	(0.2393)	(0.1348)	(0.1801)
PCT Filing Dummy	-1.0824		-0.3153	0.610	-0.3187	0.0912
	(0.8590)		(0.0861)***	(0.1608)	(0.0865)***	(0.1523)
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Assignee Dummies	No	Yes	No	Yes	No	Yes
N	370	346	4245	1870	4712	2310
Log PseudoLH	-158.3885	-125.1598	-1585.4345	-668.6749	-1866.1149	-864.7393
Pseudo R^2	0.3430	0.4411	0.3819	0.4511	0.3703	0.4463

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all USPTO (The United States Patent and Trademark Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for USPTO patent applications; column (4)-(6) reports results for USPTO patents. Heterogenous Robust standard errors are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all USPTO patents that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application, whether the patent application is a PCT application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 741 3-digit USPC fields).

Table 8: Sub-sample estimation of Technology Conditions on Choice of Chinese Patent Protection for all USPTO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.322 for all USPTO patent applications. Rates of technology obsolescence are calculated using all USPTO patents applied during 1998-2005)

Dependent Variable:	Patenting choice			
	Large STD (1)	Medium STD (2)	Small STD (3)	All (4)
Mean STD_{ijt} (*weighted USPC*)	45.6376	10.4291	3.6353	24.3402
	(22.0143)**	(7.3930)	(4.0569)	(12.2484)**
Mean STD_{ijt} * Medium STD_{ijt} Dummy				-12.7603
				(15.2491)
Mean STD_{ijt} * Large STD_{ijt} Dummy				-17.9072
				(14.5076)
Grant	-0.0039	-0.0190	-0.02953	-0.0223
	(0.1748)	(0.0900)	(0.1262)	(0.0570)
Patent Portfolio Size	0.0009	0.0010	0.0010	-0.0010
	(0.0008)	(0.0005)**	(0.006)*	(0.0003)***
Number of Claims	0.0018	-0.0187	-0.0185	-0.0155
	(0.0094)	(0.0079)	(0.0052)***	(0.0032)***
Number of Inventor	-0.1393	-0.1098	-0.1150	-0.1183
	(0.0552)**	(0.542)**	(0.0523)**	(0.0203)***
Number of Assignee		-0.9645	-0.8276	-1.0202
	(0.2774)***	(0.2247)***	(0.2286)***	
Continuation Dummy	-0.7243	0.2010	0.1286	-0.1125
	(0.4323)*	(0.2070)	(0.2007)	(0.1051)
PCT Filing Dummy	0.2925		-0.1270	-0.3291
	(0.2365)	(0.1558)	(0.1012)***	(0.0626)***
Application Year Dummies	Yes	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	Yes
N	971	1314	2129	4712
Log PseudoLH	-188.8176	-576.8352	-983.9093	-1853.2597
Pseudo R^2	0.2568	0.2886	0.3314	0.3747

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all USPTO (The United States Patent and Trademark Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for USPTO patent applications; column (4)-(6) reports results for USPTO patents. Heterogenous Robust standard errors are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all USPTO patents that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application, whether the patent application is a PCT application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 741 3-digit USPC fields).

Table 9: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to Germany)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} *(weighted IPC)*	11.7544	10.0837	9.6383	12.8782	11.5207	17.8540
	(2.1319)***	(3.4345)***	(3.4254)***	(3.2738)***	(8.3227)	(8.3437)**
Grant	-0.0957	-0.0835	-0.0028			
	(0.0841)	(0.0955)	(0.0975)			
Patent Portfolio Size			0.0007			-0.048
			(0.0014)			(0.0331)
Number of Claims			-0.0300			-0.0351
			(0.0084)***			(0.0183)*
Number of Inventor			-0.1784			(-0.2248)
			(0.0785)**			(0.2248)
Number of Assignee			-0.1131			-0.3810
			(0.1499)			(0.4834)
Continuation Dummy			0.1406			1.6596
			(0.5388)			(0.3702)***
Patent Characteristics	No	No	Yes	No	No	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes	No	Yes	Yes
N	2687	1844	1844	789	443	443
Log PseudoLH	-1222.5284	-648.2480	-630.3783	-337.1404	-113.1594	-107.5693
Pseudo R^2	0.0866	0.359	0.3698	0.1008	0.4591	0.4859

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to Germany) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 10: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to France)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} *(weighted IPC)*	9.2514	6.4675	5.8551	11.4647	6.8803	8.9992
	(1.1933)***	(2.0833)***	(1.9488)***	(1.9128)***	(4.0164)	(4.0884)**
Grant	-0.0627	-0.1196	-0.0083			
	(0.0811)	(0.0938)	(0.0982)			
Patent Portfolio Size			0.0007			-0.0449
			(0.0014)			(0.0342)
Number of Claims			-0.0300			-0.0327
			(0.0084)***			(0.01879)*
Number of Inventor			-0.1875			(-0.2147)
			(0.0772)**			(0.2207)
Number of Assignee			-0.1245			0.4144
			(0.1502)			(0.4668)
Continuation Dummy			0.1589			1.6472
			(0.5270)			(0.3680)***
Patent Characteristics	No	No	Yes	No	No	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes	No	Yes	Yes
N	2687	1844	1844	789	443	443
Log PseudoLH	-1146.8931	-671.4276	-630.3783	-302.7357	-112.7740	-107.6102
Pseudo R^2	0.1431	0.3575	0.3698	0.1925	0.4610	0.4857

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to France) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 11: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to Great Britain)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} *(weighted IPC)*	6.1836	6.4434	5.8414	7.5324	6.9627	9.0646
	(0.7772)***	(1.3446)***	(1.3505)***	(1.2237)***	(3.2296)**	(3.3325)***
Grant	-0.06820	-0.1276	-0.0179			
	(0.0755)	(0.0939)	(0.0990)			
Patent Portfolio Size			0.0004			-0.0438
			(0.0014)			(0.0333)
Number of Claims			-0.0293			-0.0377
			(0.0083)***			(0.0197)*
Number of Inventor			-0.1942			-0.2285
			(0.0773)**			(0.2236)
Number of Assignee			-0.1248			-0.4506
			(0.1523)			(0.4924)
Continuation Dummy			0.1663			1.6366
			(0.5254)			(0.3869)***
Patent Characteristics	No	No	Yes	No	No	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes	No	Yes	Yes
N	2687	1844	1844	789	443	443
Log PseudoLH	-1121.1503	-660.9236	-621.7800	-294.3156	-111.6825	-107.5693
Pseudo R^2	0.1624	0.3566	0.3784	0.2150	0.4662	0.4859

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to Great Britain) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 12: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to Germany)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} *(weighted IPC)*	11.1553	-9.7103	10.2158	-18.6989	10.3973	-19.3331
	(1.7224)***	(10.0375)	(3.4086)***	(12.5471)	(3.4471)***	(12.5577)
Mean $Grantlag_{ijt}$	-0.0003	-0.0025	-0.0007	-0.0037	-0.0004	-0.0035
	(0.0004)	(0.0013)*	(0.0005)	(0.0004)	(0.0005)	(0.0014)**
Mean STD_{ijt} * *Mean* $Grantlag_{ijt}$		0.0161		0.0224		0.0230
		(0.0081)**		(0.0096)**		(0.0096)**
Grant	-0.1048	-0.0969	-0.0883	-0.1031	-0.0042	-0.0195
	(0.0818)	(0.0791)	(0.0986)	(0.1000)	(0.1010)	(0.1026)
Patent Portfolio Size					0.0004	0.0004
					(0.0015)	(0.0015)
Number of Claims					-0.0307	-0.0308
					(0.0086)***	(0.0087)***
Number of Inventor					-0.1667	-0.1692
					(0.07962)**	(0.0789)**
Number of Assignee					-0.0908	-0.0860
					(0.1448)	(0.1448)
Continuation Dummy					0.4517	0.4447
					(0.5971)	(0.5908)
Patent Characteristics	No	No	No	No	Yes	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	No	Yes	Yes	Yes	Yes
N	2687	2687	1844	1844	1844	1844
Log PseudoLH	-1187.8238	-1180.9141	-629.8693	-626.6637	-612.6638	-609.4025
Pseudo R^2	0.0834	0.0887	0.3459	0.3492	0.3637	0.3671

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to Germany) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 13: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to France)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} (*weighted IPC*)	8.9954	2.5366	4.333	-19.7390	4.5234	-19.5439
	(1.0417)***	(5.8798)	(2.0067)**	(7.8511)**	(2.0468)**	(8.0332)**
Mean $Grantlag_{ijt}$	-0.0002	-0.0015	-0.0007	-0.0056	-0.0004	-0.0053
	(0.0003)	(0.0014)	(0.0005)	(0.0016)***	(0.0005)	(0.0016)***
Mean STD_{ijt} * *Mean* $Grantlag_{ijt}$		0.0049		0.0184		0.0184
		(0.0048)**		(0.0060)***		(0.0061)***
Grant	-0.0767	-0.0969	-0.0883	-0.1031	-0.0057	-0.0171
	(0.0800)	(0.0791)	(0.0986)	(0.1000)	(0.1018)	(0.1020)
Patent Portfolio Size					0.0005	0.0004
					(0.0015)	(0.0015)
Number of Claims					-0.0305	-0.0309
					(0.0085)***	(0.0086)***
Number of Inventor					-0.1713	-0.1733
					(0.07832)**	(0.0775)**
Number of Assignee					-0.1009	-0.0950
					(0.1452)	(0.1455)
Continuation Dummy					0.4300	0.4488
					(0.6034)	(0.5996)
Patent Characteristics	No	No	No	No	Yes	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	No	Yes	Yes	Yes	Yes
N	2687	2687	1844	1844	1844	1844
Log PseudoLH	-1116.9234	-1115.189	-631.9343	-627.0450	-614.5957	-609.8336
Pseudo R^2	0.1381	0.1395	0.3437	0.3488	0.3617	0.3667

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to France) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 14: Estimates of Technology Obsolescence on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPO patents applied during 1998-2005 and designated to Great Britain)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{ijt} *(weighted IPC)*	6.1778	3.3101	5.4877	-4.5520	5.4740	-4.3120
	(0.7313)***	(3.6939)	(1.3300)***	(6.1908)**	(1.3961)***	(6.2456)
Mean $Grantlag_{ijt}$	0.0000	-0.0005	-0.0007	-0.0025	-0.0004	-0.0022
	(0.0003)	(0.0009)	(0.0004)	(0.0011)**	(0.0004)	(0.0011)**
Mean STD_{ijt} * *Mean* $Grantlag_{ijt}$		0.0021		0.0074		0.0072
		(0.0030)		(0.0044)*		(0.0044)*
Grant	-0.0818	-0.0806	-0.0994	-0.1050	-0.0174	-0.0229
	(0.0760)	(0.0755)	(0.0994)	(0.0996)	(0.1023)	(0.1025)
Patent Portfolio Size					0.0002	0.0002
					(0.0015)	(0.0015)
Number of Claims					-0.0300	-0.0299
					(0.0085)***	(0.0086)***
Number of Inventor					-0.1791	-0.1799
					(0.07786)**	(0.0775)**
Number of Assignee					-0.0981	-0.0988
					(0.1460)	(0.1452)
Continuation Dummy					0.3969	0.4024
					(0.6177)	(0.6102)
Patent Characteristics	No	No	No	No	Yes	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	No	Yes	Yes	Yes	Yes
N	2687	2687	1844	1844	1844	1844
Log PseudoLH	-1091.2266	-1090.4577	-623.6801	-622.0637	-606.8468	-605.3578
Pseudo R^2	0.1580	0.1585	0.3523	0.3540	0.3698	0.3713

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all EPO (The European Patent Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for EPO patent applications; column (4)-(6) reports results for EPO patents. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated to Great Britain) that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit USPC fields).

Table 15: Estimates of Technology Conditions and applicants' patent portfolio size on Choice of Chinese Patent Protection for all EPO patent (applications) with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **Utility Model**, Mean=0.232 for all EPO patent applications. Rates of technology obsolescence are calculated using all EPTO patents applied during 1998-2005)

Dependent Variable:	Patenting choice					
	Germany		France		Great Britain	
	All (1)	All (2)	All (3)	All (4)	All (5)	All (6)
Mean STD_{ijt} *(weighted USPC)*	11.7108	9.9585	9.1212	6.0588	6.1827	6.3558
	(2.0742)***	(3.4846)***	(1.1996)***	(4.440)***	(0.7807)***	(1.3774)***
Large Patent Portfolio Dummy	0.6216	0.0509	0.6750	0.4723	1.1167	0.4226
	(0.7190)	(0.8315)	(0.8359)	(1.1672)	(0.4360)***	(0.5907)
Mean STD_{ijt} * Large Patent Portfolio	-3.7319	-2.1749	-2.1964	-2.6844	-4.0665	-2.8225
	(4.8973)	(5.8390)	(3.1418)	(4.2052)	(1.5076)***	(2.0509)
Grant	-0.03425	-0.0031	0.0020	-0.0073	-0.0164	0.0233
	(0.0824)	(0.0976)	(0.0811)	(0.0984)	(0.07754)	(0.0997)
Patent Portfolio Size	0.0002	0.0013	0.0020	0.0013	0.0017	0.0014
	(0.0018)	(0.0016)	(0.0018)	(0.0016)	(0.0017)	(0.0015)
Number of Claims	-0.0236	-0.0295	-0.0245	-0.0296	-0.0233	-0.0290
	(0.0083)***	(0.0083)***	(0.0077)***	(0.0091)*	(0.0069)***	(0.0083)***
Number of Inventor	-0.1938	-0.1781	-0.1726	-0.1875	-0.1669	-0.1979
	(0.0608)***	(0.0787)**	(0.0607)***	(0.0776)**	(0.0580)***	(0.0778)**
Number of Assignee	-0.3492	-0.1228	-0.3047	-0.1359	-0.3175	-0.1405
	(0.1350)***		(0.1509)	(0.1338)***	(0.1325)**	(0.1544)
Continuation Dummy	0.1893	-0.1518	0.0513	-0.1903	0.1310	-0.1550
	(0.4649)	(0.5353)	(0.4792)	(0.5146)	(0.5266)	(0.5317)
Patent Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Application Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	No	Yes	No	Yes	No	Yes
N	2687	1844	2687	1844	2687	1844
Log PseudoLH	-1177.4914	-629.7106	-1107.9551	-628.9488	-1082.5767	-619.9391
Pseudo R^2	0.1203	0.3705	0.1722	0.3712	0.1912	0.3802

Notes: Patent-Level Observation. All estimates are from profit models. Sample includes all USPTO (The United States Patent and Trademark Office) patent (applications) with Chinese Priority from 2001-2006 cohort. Column (1)-(3) reports results for USPTO patent applications; column (4)-(6) reports results for USPTO patents. Heterogenous Robust standard errors are shown in parentheses. *: p<0.10; **: p<0.05; ***: p<0.01. Dependent variable is dummy variable that equals to one if the patent is filed for *Utility Model* in China. *Mean TFR* is the average percentage of patents that are given up within 4 years from issue date for all USPTO patents that are filed in the past 3 years and in the same 3-digit USPC technology field(s) as the observed patent.*Grant* is a dummy variable that equals to one if the patent is eventually granted. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application, whether the patent application is a PCT application. *Application Year Dummies*: 0/1 indicator variable for application year. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 741 3-digit USPC fields).

Table 16: 2005 cohort rate of technology obsolescence rankings in Germany by IPC (4-digit)

Technology Fields	Rank	IPC	TFR
Small rate of technology obsolescence			
Hybrid Computing Arrangement	1	G06J	0
Vehicles Drawn by Animals	2	B62C	0
Aids for Music	3	G10G	3.40%
Thread Cutting	4	B23G	3.45%
Electromechanical Clocks or Watches	5	G04C	4.89%
Medium rate of technology obsolescence			
Refrigeration Machines	304	F25B	14.42%
Machine for Making Railway	305	E01B	14.44%
Marine Propulsion or Steering	306	B63H	14.44%
Wall, Floor Covering Material	307	D06N	14.46%
Organic Dyes	308	C09B	14.46%
Large rate of technology obsolescence			
Sports, Game, Amusement	604	A63K	38.88%
Preparing Grain for Milling	605	B02B	40.42%
Fermented Solutions By-Products	606	C12F	42.38%
Organs, Harmonious Musical Instrument	607	G10B	44.44%
Preserving Wood	608	B27J	50%

Table 17: Changes in rate of technology obsolescence 2000-2005 in Germany, IPC 4-digit

Technology Fields	Rank	IPC	TFR changes
Biggest decrease in rate of technology obsolescence			
Dovetailed Work, Tenons, Nailing	1	B27F	-36.17%
Steam or Vapor Condensers	2	F28B	-32.56%
Safety Device, Transport in Mines	3	E21F	-28.03%
Making Chains	4	B21L	-26.58%
Weapons for Projecting Missiles without Charging	5	F41B	-26.32%
Smallest change in rate of technology obsolescence			
Making Boxes, Cartons, Envelops	509	B31B	-0.16%
Treating Skins, Hides with Chemicals	510	C14C	-0.08%
Printing Machines or Presses	511	B41F	-0.08%
Auxilieries on Vessels	512	B63J	0.22%
Steam Engines Plants	513	F01K	0.22%
Biggest increase in rate of technology obsolescence			
Heat-Exchange Apparatus	737	F28C	11.56%
Launching Missiles from Barrels	738	F41F	12.87%
Saccharides	739	C13K	14.07%
Auxiliary Weaving Apparatus	740	D03J	17.49%
Furnishing for Windows or Doors	741	A47H	23.88%

Table 18: 2005 cohort rate of technology obsolescence rankings in France by IPC (4-digit)

Technology Fields	Rank	IPC	TFR
Small rate of technology obsolescence			
Gas Holders of Variable Capacity	1	F17B	0
Phosphatic Fertilisers	2	C05B	7.40%
Saddlery; Upholstery	3	B68F	8.33%
Nuclear Reactor	4	G21C	13.22%
Artificial Flowers	5	A41G	13.62%
Medium rate of technology obsolescence			
Foundry Moulding	304	B22C	27.76%
Measuring Length, Thickness	305	G01B	27.85%
Couplings for Transmitting Rotation	306	F16D	27.89%
Sanitary Equipment, Toilet Accessories	307	A47K	27.90%
Wind Motors	308	F03D	27.93%
Large rate of technology obsolescence			
Auxiliary Weaving Apparatus	604	D03J	58.11%
Embroidering	605	D05C	59.13%
Safety Device, Transport in Mine	606	E21F	59.50%
Spinning or Twisting	607	D01H	65.03%
Warping, Beaming or Leasing	608	D02H	65.08%

Table 19: Changes in rate of technology obsolescence 2000-2005 in France, IPC 4-digit

Technology Fields	Rank	IPC	TFR changes
Biggest decrease in rate of technology obsolescence			
Making Chains	1	B27F	-28.75%
Disposal of Solid Waste	2	F28B	-27.33%
Apparatus for Processing exposed Photographic Material	3	E21F	-25.82%
Mechanical Treatment of Natural Fibrous material	4	B21L	-25.37%
Walking Sticks, Umbrella	5	F41B	-24.65%
Smallest change in rate of technology obsolescence			
Soldering, Welding, Cladding	387	B31B	-0.07%
Non-Mechanical Removal of Metallic Material	388	C14C	-0.06%
Macromolecular Compounds	389	B41F	-0.04%
Shaping or Joining of Plastics	390	B63J	0.01%
Mixing	391	F01K	0.06%
Biggest increase in rate of technology obsolescence			
Ammonia, Cyanogen	737	F28C	22.26%
Engine Driven by Liqiuds	738	F41F	23.13%
Removing Bank or Vestiges of Branches	739	C13K	24.77%
Furnishing for Windows or Doors	740	D03J	31.44%
Embroidering	741	A47H	34.20%

Table 20: 2005 cohort rate of technology obsolescence rankings in Great Britain by IPC (4-digit)

Technology Fields	Rank	IPC	TFR
Small rate of technology obsolescence			
Optical Computing Devices	1	G06E	0
Phosphatic Fertiliser	2	G05B	7.40%
Non-Positive-Displacement Machines	3	F01D	8.33%
Saddlery; Upholstery	4	B68F	13.22%
Produing a Reactive Propulsive Thrust	5	F03H	13.62%
Medium rate of technology obsolescence			
Measuring Force, Stress, Torque	304	G01L	27.76%
Electrostatic Separation of Solid Material	305	B03C	27.85%
Measuring Temperature, Quantity of Heat	306	G01K	27.89%
Outerwear; Protective Garments	307	A41D	27.90%
General Methods of Organic Chemistry	308	C07B	27.93%
Large rate of technology obsolescence			
Recovery of By-Product of Ferment solutions	604	C12F	58.11%
Brakes specially adapted for Cycles	605	B62L	59.13%
Skates, Skis; Roller Skates	606	A63C	59.50%
Spinning or Twisting	607	D01H	65.03%
Making Chains	608	B21L	65.08%

Table 21: Changes in rate of technology obsolescence 2000-2005 in Great Britain, IPC 4-digit

Technology Fields	Rank	IPC	TFR changes
Biggest decrease in rate of technology obsolescence			
Disposal of Solid Waste	1	B09C	-31.16%
Steam or Vapor Condensers	2	F28B	-25.77%
Making wound articles	3	B31C	-25.57%
Lightning Devices	4	F21L	-24.94%
Lighter-than-Air-Aircraft	5	B64B	-24.03%
Smallest change in rate of technology obsolescence			
Drying Solid Materials	409	F26B	-0.07%
Apparatus for applying liquid to Surface	410	B05C	-0.03%
Fire-Fighting	411	A62C	-0.01%
Vehicles suspension arrangement	412	B60G	0.006%
Finishing, Textile fabrics	413	D06C	0.17%
Biggest increase in rate of technology obsolescence			
Boiling Apparatus	737	B01B	27.32%
Constructional Details of Instruments	738	G12B	27.81%
Furnishing for Windows or Doors	739	A47H	28.24%
Heat-exchange Apparatus	740	F28C	28.39%
Fastening Footwears	741	A43C	32.43%