Speed of Patent Protection, Rate of Technical Knowledge Obsolescence and Optimal Patent Strategy: Evidence from Innovations Patented in the US, China and several other countries

Job Market Paper

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Abstract

When technology develops faster, how will firms adjust their patenting strategies? Using a dataset with information about patent applications in both China and the US, I find that firms are willing to secure early patent grants when technology moves ahead faster. The conventional wisdom that a patent secures a flow of monopoly profits that depreciates at a constant speed over time is not consistent with my empirical findings. Faster technology progress shifts the profits towards the early periods, making early grants more important. The empirical results suggest that a more flexible patent regime which offers options for speed is more efficient.

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1 INTRODUCTION

A rich set of economic literature investigates the strategic implications of the patent regime for firm-level patenting behaviors (Levin et al. 1987, Cohen, Nelson, and Walsh 2000, Hall and Ziedonis 2001). Strengthening appropriability conditions[2] (such as increasing duration and scope of patent protection) is likely to have both positive and negative influences on the private returns to firms' patents.[3] An interesting yet somehow under-explored strand of literature is to consider how firms address the benefits and costs of given appropriability conditions (Ahuja, Lampert, and Tandon 2008). In theory, given that firms are strategic players, one would expect that firm strategies would try to utilize the advantage of appropriability conditions to maximize the private returns to their patents. These private returns to patent do not, however, depend only on the institutional design of the patent regime. New discoveries and improvements in technology might alter the value of a firm's existing and future innovations which, in turn, imply adjustments of its patenting behaviors.

This paper provides empirical evidence that a firm's patenting strategy is determined by the rate of technical knowledge obsolescence embedded in patents. I quantify the effect of this knowledge obsolescence on Chinese firms' patenting decisions across more than 400 distinct technology fields during 2001-2006, a period during which no major shifts in the patent regime took place in China. My results indicate that, when new technical knowledge supersedes existing technical knowledge at a faster pace, firms are more willing to secure early patent grants for their innovations. I show that these patterns from the data are consistent with a firm-level return-to-patent maximization problem used commonly in the innovation literature (Nordhaus 1969; Gilbert and Shapiro 1990; Gallini 1992), with one additional assumption: the return to a patent depends on how quickly the current technological knowledge becomes obsolescent, which is treated as exogenous to the firm and characterized by a constant depreciation factor over time. A firm forms expectations about the impact of rate of knowledge obsolescence on the private returns to its own patents based on its current stock of technical knowledge and adjusts its patenting strategies according to the following rule: given that the firm's stock of technical knowledge is fixed, higher rates of technological knowledge obsolescence shift the reward to a patent towards the early periods of patent life, inducing the firm to secure early patent grants in order to maximize the benefits of the patent right.

[2]Appropriability conditions refer to the environmental factors, apart from firm and market structure, that enable an innovator to capture the rents of innovation (Teece 1986). The patent system is the most widespread and commonly studied appropriability mechanism in the context of innovation. Other mechanisms include secrecy, lead-time advantage, trademark, copyright etc. In this paper, I only focus on the appropriability implications of a patent regime.

[3]A strong patent regime alleviates the concern of expropriation by rivals and affords the innovative firms with an opportunity to recover investments in research and development (R&D) (Arrow 1962, Anton and Yao 1994); it might also discourage research because strong patent rights make it more difficult to "invent around" a prior innovation (Gallini 1992), discouraging follow-on research. O'donoghue, Scotchmer, and Thisse (1998) introduced the concept of *leading breadth* and *lagging breadth* and analyze the optimal design of a patent regime for sequential innovations.

Delay in patent protection has been a universal problem for big patent offices such as the United States Patent and Trademark Office (USPTO), the European Patent office (EPO) and the State Intellectual Patent Office of China (SIPO). A recent report of USPTO concludes that patent pendency could cost the US economy billions of dollars annually in "forgone innovation"–business opportunities that fail to get off the ground due to the late arrival of patents.[4] There has been a long history of major patent offices offering a uniform patent application process.[5] The institutional design of the patent regime in the US and Europe, therefore, prevents us from understanding the determinants of firms' demand for speed of patent protection. To address this issue, I utilize a policy design provided by the State Intellectual Patent Office of China (SIPO), which provides two types of patent protection for product innovation, namely, the invention patent and the utility model. Utility model protection is granted much faster than invention patent protection (an average of one year as compared to 4.5 years) because an application for utility model protection does not require a complete and substantial patent examination. A firm's choice of utility model might, however, also suggest that the invention represents low technical quality. In order to distinguish between firms' concerns for speed and quality, I carefully select the sample to include inventions for which patents are sought in both China and the United States. The United States Patent and Trademark Office (USPTO) employs a uniform and rigorous patent examination standard, which is presumably at least comparable to the patentability standard for the invention patent in China. I find that although firms choose the utility model available in China for a significant potion of their innovations, the overall US grant rates for US patents with Chinese utility model and invention patent priorities[6] are almost identical. In other words, some firms that have innovations that qualify for full patent protection are choosing weaker and faster protection. I also conduct the analysis using inventions for which patents are sought in both China and Europe and find the results are consistent with the results found in the China-US patent sample.

[4] In the past few years (2009-), USPTO has repeatedly mentioned its grave concerns about the impact of patent pendency on future innovation and economy. These occasions include speeches by David Kappos (former Director of the USPTO) during the Innovation Alliance Conference (Jan. 2011), World IP Day (Apr. 2012), Center for American Progress (Jun. 2010), a US Dept. of Commence Report on the Role of Patent Reform in Supporting Innovation and Job Creation (Apr 2010) and many others.

[5] It was not until 2011 that the United States Patent Office (USPTO) decided to undergo a shift in the patent application process that introduced "fast track" patent examination. It allows applicants, subject to a hefty fee, to obtain a final disposal within 12 months from the filing date. The EPO, on the other hand, still offers a single route for patent applications.

[6] In both the US and Chinese patent law, a priority right is a time-limited right, triggered by the first filing of an application for a patent. The priority right allows for claimant to file a subsequent application in another country for the same invention effective as of the date of filing the first application. When filing the subsequent application, the applicant must claim the priority of the first application in order to make use of the right of priority.

The previous literature offers no consensus measure of the rate of technical knowledge obsolescence.[7] I extend Bosworth's approach to use patent renewal data to create a proxy variable for the rate of obsolescence (Bosworth 1978). The index is based on the idea that the duration of a patent reflects the lifetime of the technical knowledge embedded in the patent. More specifically, when an incumbent technology's competitive advantage diminishes due to emergence of some superior technical knowledge, the private value of the associated patent will decrease, contributing to an early mortality of the patent right. Individual patent renewal decisions have been used extensively in the literature as a means to estimating private returns to patent (Pakes 1986; Schankerman and Pakes 1987; Lanjouw and Schankerman 2004 etc.). Instead of focusing on the renewal decisions of the entire lifespan of a given patent cohort, I look at the percentages of ineffective patent rights (based on renewal decisions) for a given age of patents over different cohorts and treat them as a continuous measure of technical knowledge obsolescence.

My identification exploits within-technology variation of the above indices over time. A key advantage of this approach is that it mitigates concerns of comparing patenting behaviors across different technology fields.[8] The empirical analysis indicates that, when development of technical knowledge is carried out at a faster pace, firms' propensity for choosing the utility model increases. One standard deviation increase in the rate of technical knowledge obsolescence increases firms' propensity to file for the utility model by 6%-8%. I find the sensitivity in the choice of utility model is non-uniform across technology obsolescences: the largest effect is in fields with a technology index above the 67^{th} percentile of the distribution. I also find evidence that the sensitivity to changes in technological progress can be decomposed into a firm "entry and exit" effect and a shift in the patenting strategy of existing firms, with the magnitude of the second effect much larger than that of the first. I find that these within-technology variations in the rate of technological progress reflect distinct patenting strategies depending on the size of the individual firm's patent portfolio: firms with almost no stock of patents are most sensitive to the changes in technology development whereas firms with a sizable stock of patent follow a more stable patenting strategy. This result is consistent with previous literature showing that startup firms pursue patent rights for financing and licensing considerations (Gans, Hsu, and Stern 2008).

[7] Bosworth uses patent renewal to characterize the rate of technical knowledge obsolescence (Bosworth 1978). Comin, Diego and Hobijn use the changes in market share of existing technologies vs. new technologies as a measure of how quickly technology becomes obsolete (Comin and Hobijn 2004). Bilir uses average patent citation lag as a measure of technology cycle (Bilir 2013).

[8] As discussed extensively in the literature, the effectiveness of patents varies significantly across different technology areas (Merges and Nelson 1990; Levin et al. 1987; Cohen, Nelson, and Walsh 2000; Burk and Lemley 2003)

To consolidate my results, I exploit exogenous variations in SIPO's administrative efficiency in examining invention patents. I find that when SIPO examines invention patents more efficiently (as represented by a shorter aggregate grant lag), there is a decrease in the sensitivity in the choice of the utility model to the speed of technological change, a result consistent with my hypothesis that patent pendency is an important concern for firms while filing patents.

My paper is related to several different strands of literature. The analysis contributes to a growing body of work that evaluates the distortion of innovation under a uniform patent system. Using exogenous variation in a clinical trial period, Budish et al. 2013 find that a fixed patent term shifts private R&D resources towards pharmaceutical drugs with shorter commercialization delay. O'Donoghue and Zweimüller 2004 incorporate the fixed attributes of the patent system into a dynamic endogenous growth model and conclude that a uniform patent system causes misallocation of resources across industries. From a different perspective, this paper empirically demonstrates firms' heterogenous demand for speed of patent protection and suggests that current patent regimes that employ a uniform patent application standard might be no longer as effective as before when technology is progressing rapidly. Previous economic and legal literature has focused on other aspects of patent policy (e.g. patent scope, length, validity etc). My paper, which examines the importance of patent pendency in addition to patent length and scope as a public policy instrument in addition to length and scope, adds insight into the optimal design of patent systems.

This paper also makes a methodological contribution to the literature on patent evaluation, by providing a novel perspective on the use of patent renewal as an indicators of private patent value. Given that it is considerably more expensive for Chinese firms to file overseas at USPTO, my results are not consistent with the previous understanding that patents are not renewed because they are no longer valuable inventions. Rather, they are abandoned sooner because the flow of value they bring to the patentees is more heavily weighted toward the early years of patent life. The value flow is likely to be high in the early years for these patents, but to decline quickly to a level at which marginal expected returns are insufficient to justify further renewal expenditure. The paper shed lights on a growing research line that explores patentee behavior regarding equivalent inventions in different patent system, offering insight into firm patenting strategies as well as institutional differences across patent systems.

The paper proceeds as follow: section 2 outlines some of the key provisional differences of Chinese invention patent and utility model; section 3 lays out a simple theory and a historical example in the electrical lightning industry to elaborate our economic intuition; section 4 discusses our definition of the rate of technical knowledge obsolescence; section 5 describes our data and summary statistics of all regression variables; section 6 presents our econometric model and identification strategy; section

7 and 8 report our empricia findings and robustness checks; section 9 concludes.

2 Chinese Invention Patent vs. Utility Model

This section briefly compares some of the important provisional differences between the Chinese invention patent and the Chinese utility model. It serves as the foundation upon which I develop my research design and sample construction.

2.1 Delay in Patent Pendency

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. The invention patent is the conventional patent: the application will go through a substantial examination for novelty, inventiveness and practicability. The Chinese utility model is designed following the German and Japanese utility model. This lesser-known form of IP protection was initially designed to protect property rights in a way 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 patent pendency for a utility model typically ranges from six months to a one year and a half (average 14 months), as against four to five years (average 4.5 years) for an invention patent. Figure 2 illustrates the mean grant lags of Chinese invention patent and utility models by application year for the period 1985-2011. Invention patents are granted, on average, 1621 days (or 54 months) after, application with a minimum average of 732 days (per year) and a maximum average of 2148 days (per year). In contrast, utility models are granted, on average, 434 days (14 months), with a minimum annual of only 199 days (per year) and a maximum annual of 599 days (per year). In addition, there is a large variation in the grant lag of the invention patents over time (std. dev: 337 days), whereas average grant lag for the utility models remains relatively stable (std. dev: 109 days).

2.2 Application, Attorney and Maintenance Costs

Table 1 presents the legal provisions, and the process of granting and maintenance of the Chinese invention patent and the Chinese utility model. Besides the advantage of a fast patent grant, the utility model is also more attractive because it is significantly cheaper than the invention patent. For instance, preparation of a utility model application through a Chinese attorney typically costs an applicant $500 (3000 *rmb*), whereas that for an invention patent is around $1,300 (8000 *rmb*),[9] an amount more than double. The differences in maintenance costs over the first ten years after patent issue are also

[9]Cost of attorney is based on interviews with one senior patent attorney at *Tee* & *Howe*, an IP law firm licensed by the Chinese government to represent domestic and foreign clients.

significant: the aggregate cost of renewing a utility model is about 60% the cost of renewing an invention patent for the same effective periods. Since the application for a utility model does not require examination, the application fee for a utility model is significantly lower. Overall, the total cost of applying and maintaining a utility model is around 30% of the cost of applying and maintaining an invention patent.

2.3 Patent Scope and Validity Issues

The Chinese Patent Law does not set different patent scope standards for the invention patent and the utility model.[10] In addition, the bases for claiming damages caused by patent infringement on an invention patent and a utility model are the same.[11] However, when infringement litigation is filed for a utility model, the plaintiff is required to present an evaluation report prepared by SIPO during the proceeding as evidence supporting its validity. In China, the validity of an invention patent or a utility model is determined by the Patent Reexamination Board rather than by a court. An assertion of patent validity, therefore, often results in a delay at the court while the validity is pending. In addition, the credibility of a utility model's evaluation report is subject to many concerns. Before 2009, SIPO personnel in charge of preparing the report is selected from a pool of examiners who did not represent the most qualified examiners in each technology field. The resources available for prior art search are limited to prior Chinese invention patents and utility models, which limits the examiners' ability to get access to other sources such as academic journals, other online publications and issued patents in foreign countries. Moreover, the evaluation report is not an "ironclad" proof of the utility model's validity. That is to say, even if the report fails to find the utility model invalid, other evidence might overturn the utility model's validity.

Based on the above evidence, I treat the Chinese utility model as a faster and cheaper but weaker IP protection compared to the Chinese invention patent.

[10] According to Chinese Patent Law (2008) Article 11: After the patent right is granted for an invention or a utility model...no...individual may... manufacture, use, sell or import the patented products without permission of the patentee.

[11] The 2000 Amendment of the Chinese Patent Law sets forth a standard for calculating infringement damages based on four alternative methods: lost profit to the patentee, unjust enrichment to the infringer, exploitation fee for the patent under contractual license and a statutory amount between $10,000$ rmb to $1000,000$ rmb, depending on various factors related to the characteristics of patent right and infringement.

3 The Strategic Implications of Patent Pendency under Technology Progress: Explanation and Historical Example

This section is divided into three parts. The first part outlines our economic interpretation that a firm's propensity to secure early patent rights (or shorten patent pendency) is determined by changes in the rate of technical knowledge obsolescence. The second part describes a historical example in the electric lamp industry that follows the above intuition closely. The third part applies this intuition to a choice model in which firms can select between the Chinese invention patent and utility model to maximize the private returns to their patents. Based on this model, we derive several theoretical implications that will be empirically tested.

3.1 Patent Pendency as Firm Strategy

Under both US and Chinese patent laws, a patent right becomes effective after the patent office issues the patent. Conditioning on the grant, a patent owner can obtain reasonable royalty damages for infringement activities that occur after the patent publication, an event that happens no later than 18 months from application (and, in most cases, much earlier than the patent grant).[12] Assuming firms are risk neutral and aware of the probability of the patent grant,[13] firms might want to secure the patent grant early, rather than late, because early resolution of uncertainty contributes to long-term planning (Epstein, Farhi, and Strzalecki 2013).

Research-oriented firms treat patents as their strategic assets and use them in many different ways. More specifically, firms utilize their patents (or patent portfolios) for cross-licensing negotiations, patent-pool construction, standard-setting organizations, preemptions, defense against litigation, financing purposes and branding (Lemley 2000). In the above cases, an early patent grant contributes to the gains of specific technological or market advantage. For example, shorter pendency accelerates a firm's buildup of its patent portfolio, improving its bargaining position in cross-licensing negotiations and its defense against litigation (Cohen, Nelson, and Walsh 2000). For individual start-up firms,

[12]In the US, there are several conditions that need to be satisfied before the patentee can claim retrospective damages for infringement before a patent grant. One of the key conditions is that the patented claims need to be substantially identical to the claims in the published application (Title 35 of the United States Code 154). The Chinese patent law, on the other hand, also permits the patentee to claim retrospective royalty damages (*Chinese Patent Law 2008* Article 13). Legal practices in China, however, suggest that the infringement behaviors will be based on either the claims described in the patent publication or the finalized patent, depending on which is narrower in scope in relation to the infringed claim(s). See, e.g., court case on Chinese Patent No. 94111546.1. In summary, repeated negotiations between a patent applicant and the patent examiner are likely to subject the scope of the patent right to significant uncertainty (Merrill, Cohen, et al. 2003), making unauthorized imitation behavior economically attractive despite the litigation risk.

[13]The US patent grant rate is around 90% when accounting for "continuing patent applications" (Quillen and Webster 2001). The Chinese invention patent grant rate is around 33%. The Chinese utility model grant rate is almost one.

patent grants improve the efficiency of forming licensing contracts with their downstream manufacturers (Gans, Hsu, and Stern 2008). These firms might also secure patent grants for the purpose of meeting venture capitalists' milestones (Kortum and Lerner 2000). These studies suggest that there is an option value associated with having patents granted early.

On the other hand, firms might strategically lengthen the patent process because they expect that a patent issued later will be more valuable than one issued earlier. This value might come from catching rivals "off-guard" – the ability to force competitors into licensing contracts through the practice of "submarine patenting" (Graham and Mowrey 2004). In addition, firms might file patents without a thorough advance understanding of their commercial values. In this case, firms can take advantage of the patent pendency delay to refine their claims as they figure out how the market unravels overtime (Lemley and Moore 2004).

These studies suggest that firm strategies should take advantage of patent pendency to maximize the benefits of patent rights while minimizing their profit-reducing effects. In the classic incentive theory of patent systems, owning a patent right is treated as securing a stream of monopoly profits, the size of which depends on the institutional design of the patent (length, breadth, validity), the characteristics of the firm, market and technology.[14] In this scenario, an inventor faces a maximization problem (either profit or private return to patent) with respect to different approriability conditions (longer vs. shorter patent pendency, among others). Based on the intuition from Bosworth (1978), I treat the speed of technological progress as a constant depreciation factor on the private value of the patent over time. Faster discovery of new and superior technical knowledge is represented as a higher degree of depreciation and shorter value horizon of the patent. This is because, when an incumbent technology's competitive advantage diminishes due to emergence of a superior technology, the private value of the associated patent will decrease and the effective value horizon of the patent will be shortened. In this case, it is straightforward to see that firms will have a stronger incentive to secure early patent grants if new technologies are emerging at a faster rate.

3.2 A historical example in the Electric Lamp Industry

To be more concrete, consider for example the dramatic changes in the R&D (research and development) efforts and patenting behaviors of General Electric's major competitor, Westinghouse, before and after Thomas Edison's discovery of the incandescent lamp. Edison was the first to discover and patent an incandescent lamp with fibrous material illuminants.[15] The patent was filed in November

[14] See e.g. Gallini and Scotchmer for a literature review on optimal design of patent policy.
[15] U.S. patent No. 223,898.

1879 and quickly issued in less than 3 months in the United States.[16] Later on, Edison produced incandescent lamps using an illuminant of carbonized paper, which proved to be of huge commercial value. The development of the technology, like many other electric goods, was a cumulative nature. Westinghouse, on the other hand, also had patent rights over many related technological progresses subsequent to Edison's core patent. However, Westinghouse was producing incandescent lamps that were substantially similar to the Edison lamp, a potential infringement behavior (Bright 1972). In 1891, Edison's core patent was held valid in court. General Electric quickly obtained a series of injunctions that shut down many competitors, including Westinghouse.[17] Getting caught off-guard, Westinghouse responded by *speeding up* its R&D and patenting effort of an older and non-infringing technology.[18] In addition, Westinghouse also employed a "defensive patenting" strategy by trying to obtain patent rights related to the incandescent lamp, as fast as possible and as many as possible. For instance, one of its subsidiary firms, the Consolidated Electric Light Company, undertook to assert its right over another important incandescent lamp patent–the paper illuminant patent by Sawyer and Man[19]– immediately after the patent was granted.[20] Although Edison's patent helped his company gain a market share of around 75%, the non-infringing lamp of Westinghouse was nonetheless produced at a commercial scale large enough to help the company survive until Edison's core patent expired about 6 years later. Thereafter, Westinghouse immediately resumed production of Edison's lamp. Patent applications in the late 19 century US would be granted only after a few months. Compared to the 17 years of statutory protection, patent pendency was not even an issue. Nevertheless, Westinghouse's R&D and patenting strategies reflected its intention of securing *early*, rather than late, patent rights, when its current and future profits (and private returns to patent as well) were seriously threatened by the introduction of a superior technology.

3.3 Theory

In this section, I apply the above intuition to a concrete setting under the Chinese patent regime that offers both the invention patent and the utility model. I develop a model that captures the essential trade-off between getting a patent quickly, but with weaker protection (in terms of length and breadth), and getting a patent through a slower process that provides stronger protection for the same innovation. In particular, I examine whether the relative efficiency changes with exogenous variations in the rate

[16]Edison also filed international patent applications for the same innovation in Britain, Canada and France around the same date as when he filed the U.S. patent application. In Britain and France, the patents were granted within 2 weeks.

[17]General Electric did not allow competitors to stay in the industry even as licensees (Bright 1972).

[18]The lamp produced by Westinghouse employed the older stoppered base instead of a hermetically sealed glass globe which maintained the vacuum more steadily (Bright 1972).

[19]William E. Sawyer and Albon Man, like Edison, contributed significantly to the technical improvement and commercialization of the incandescent electric lighting industry.

[20]The Saywer and Man paper illuminant patent was granted in 1885, 6 years before Edison's patent was held valid in court, but later than when Edison started the litigation.

of technical knowledge obsolescence. 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 are excluded from the model because they do not provide further insight into the questions at issue.

A patent secures a flow of monopoly profits that depends on the strength of the patent (see Nordhaus (1969), Gilbert and Shapiro (1990), Gallini (1992) etc). To highlight the importance of speed, I add in another variable that depicts patent pendency. The optimal choice between a Tier 1 and Tier 2 patent is based on an *ex-ante* pre-filing profit flow comparison: because a Tier 2 patent is granted early, it secures profits primarily in the early periods of patent life, while a Tier 1 patent secures profits in later periods. Time is continuous in the model. My approach formalizes the intuition that the relative effectiveness of these two types of patents is affected by changes in the rate of technical knowledge obsolescence. The model is also relevant in the presence of strategic patenting, as I will discuss in the last part of this section.

This model permits examination of the relationship of research and innovation to the profits flowing from patented technologies. Specifically, I assume that firms compete in $R\&D$ in a number of technology areas indexed by j, $j = 1, \cdots J$. Technology areas are characterized by the rate of technical knowledge 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 research achieves technological breakthroughs, the state of the art is pushed forward. A new innovation thus has value to its owner until the technology it is utilizing becomes obsolescent. When technology becomes obsolescent, I assume that the associated product will lose its value for customers and that the intellectual property (invention patent or utility model), will lose its value for the owner.

For simplicity, I assume the firm has already decided to seek a patent instead of using informal mechanisms to protect the innovation.[21] The firm's problem is to select between the invention patent and the utility model to maximize the *ex-ante* flow of profit. I assume that imitation can reduce the patentee's per-period monopoly profit, depending on the scope of the patent.[22] The rate of technology obsolescence determines the maximum periods of monopoly the patentee can enjoy. Higher STD_j

[21] Some of the most frequently used tacit mechanisms include secrecy, lead-time advantage, complementary assets etc (Cohen, Nelson, and Walsh 2000). 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.

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

corresponds to shorter periods of monopoly and thus shorter periods of effective patent life. When the application is still pending, the applicant does not have the legal patent right, which often results in delayed business cooperation and early infringement. The *ex-post* profit is therefore also affected by how early the patent can be issued.[23] In this model, I assume applicants can expedite the patent examination process only through filing for the fast patent.

Suppose a patent application is filed with PTO at $t = 0$. Then patent protection can be described by three factors: (t, b, T), where t is the starting period of the effective patent right (the date of patent allowance); b is the breadth of patent, which can take a value in the interval $[0, 1]$, with $b = 0$ corresponding to a zero-effectiveness patent that allows free imitation from competitors, and $b = 1$ corresponding to perfect patent protection that blocks imitation until the the end of patent life; and T is the ending period of a statutory patent. The rate of technical knowledge obsolescence STD_j is defined as a patent value depreciation factor: ρ_j. A higher rate of obsolescence corresponds to a higher ρ_j, which makes the monopoly profits depreciate 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 and the rate of technical knowledge obsolescence together will determine the patent "shut-down" period.[24]

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

$$\pi \cdot e^{-\rho} T = c \quad (1)$$

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

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

[23] Although examination is partly affected by the applicants' response to referee reports, most of the time delay can be attributed to PTO administration and backlog frictions (Popp, Juhl, and Johnson 2003).

[24] At major PTOs in the world, patent renewal fees have been increasing over time. However, increasing renewal fees in this model will not add further insight.

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

$$\begin{aligned} \Pi_2 - \Pi_1 \;=\; & \int_{t_2}^{t_1} e^{-rs} \cdot (b_2\pi \cdot e^{-\rho s} - c)ds \\ & - \int_{t_1}^{min(T_2, \frac{1}{\rho}\cdot log\frac{b_2\pi}{c})} e^{-rs} \cdot ((b_1 - b_2)\pi \cdot e^{-\rho s})ds \\ & - \int_{min(T_2, \frac{1}{\rho}\cdot log\frac{b_2\pi}{c})}^{min(T_1, \frac{1}{\rho}\cdot log\frac{b_1\pi}{c})} e^{-rs} \cdot (b_1\pi \cdot e^{-\rho s} - c)ds \end{aligned} \tag{5}$$

Tier 2 patent offers more profits in the earlier periods because it is granted earlier, $t_2 < t_1$. However, a 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 a Tier 2 patent will outperform a Tier 1 patent if and only if the differences in profit during the early periods outweigh the differences in profit during the later periods. Notice that (5) is weakly increasing in T_1. That is, if the Tier 1 patent is granted faster, the advantage of the Tier 2 patent will become smaller. For ρ smaller than a threshold value and T_1 larger than a threshold value, $\Pi_2 - \Pi_1 < 0$ and the patent applicant will prefer a Tier 1 patent to a Tier 2 patent.

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

$$e^{-rt_2} \leq e^{-rt_1} + e^{-rT_2} \tag{6}$$

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

Proof: please see appendix for details of proof.

In other words, a patent applicant will prefer the Tier 1 patent because most of the profit will accrue during the later periods of the patent life (i.e., there is a small ρ); this later period would not be covered by a Tier 2 patent. This roughly corresponds to the case of the pharmaceutical industry, as pharmaceutical firms generally renew their patents to full term, since most of the profits is secured during the later periods of patent life (Budish, Roin, and Williams 2013).

When the rate of technology obsolescence becomes greater, the per-period profits depreciate at a faster speed. In that case, a Tier 2 patent is more favorable, because a Tier 2 patent secures early periods of profit. Simultaneously, a Tier 1 patent becomes less attractive because profits in the later periods might even fall short of the patent renewal costs.

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

$$\frac{b_2\pi}{c}^{-(\frac{rt_1}{logb_1\pi - logc})+1} - \frac{b_1\pi}{c}^{-(\frac{rt_1}{logb_1\pi - c})+1} + e^{-(rt_1 + logb_1\pi - logc)} - e^{-(rt_2 + \frac{t_2}{T_1}(logb_1\pi - logc))} > 0 \tag{7}$$

$$\frac{1}{t_1}log\frac{b_2\pi}{c} > \frac{1}{T_1}log\frac{b_1\pi}{c} \tag{8}$$

$\Pi_2 - \Pi_1$ *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 $Proposition 1$ regulate the exogenous variables (t_1, b_1, T_1) and (t_2, b_2, T_2) such that either a Tier 1 patent or a Tier 2 patent will be preferable depending on the rate of technical knowledge obsolescence.

Based on this simple setup, however, the model predicts that a faster rate of technological obsolescence tends to make a Tier 2 patent more attractive than a 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 has an interesting economic interpretation. $\rho > \frac{1}{T_1}log\frac{b_1\pi}{c}$ corresponds to the range of technical knowledge obsolescence in which 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 renewed 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 this empirical exercise.

Because the Tier 2 patent (the utility model) is a registration model, the assumption that t_2 is fixed seems to be plausible. On the other hand, in major PTOs, backlogs are creating a significant variation in terms of Tier 1 patent examination; these backlogs can be attributed to communication frictions, the extent of the examiners' diligence, the need for a thorough check of novelty and non-obviousness based upon existing prior art. 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 are likely to influence the effect of technical knowledge obsolescence on the propensity to choose Tier 2 relative to Tier 1.

Given the rate of technical knowledge 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 patents will make Tier 2 patent more favorable. Because the difference in profits is a continuous function of ρ, there exists a group of marginal "ρ" applicants who are willing to shift from filing for Tier 1 to Tier 2 patent when t_1 increases. A greater t_1, therefore, corresponds to a smaller range of ρ applicants that find a 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.

This model can also shed light on decisions about when to file for a patent, under the assumption that firms treat patent portfolios as their strategic assets. A rich set of literature has discussed the issue of strategic patenting, especially after the "pro-patent" shift with the establishment of the Court of Appeals of the Federal Circuit (CAFC) by the US Congress in 1982. Among the formal and tacit mechanisms to protect intellectual property, patents are relatively inefficient in terms of appropriating returns to R&D (Cohen, Nelson, and Walsh 2000).

The decision to patent differs by firm characteristics. Firms with large patent portfolios exploit patent rights for preemptive purposes (Gilbert and Newbery 1982), strengthening cross-licensing bargains (Hall and Ziedonis 2001), defense against potential litigation(Lanjouw and Schankerman 2001). Firms with small or no stock of patents (e.g. research-oriented start-up firms) might emphasize fast patent grants, "iron-clad" patents for purposes such as securing VC funding, and licensing agreements, signaling strong R&D abilities and enhancing competition potential.

The ability to protect IP is, thus, influenced by patent portfolio characteristics. Specifically, a firm can enhance protection on a particular patent by threatening rivals and imitators with his other patents. A firm can also preempt a rival's entry by filing "sleeping patents" or creating "thickets" of patents. The ability to file a patent for strategic purposes is largely influenced by the stock of patents owned by the firm. Technology obsolescence is thus likely to have differential effects on patenting strategy across firms with heterogeneous patent portfolio size [25]. The relative differences between Tier 1 and Tier 2 patents should be smaller for firms with larger patent portfolios.

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

4 Measuring Rate of Technical Knowledge Obsolescence

The rate of technical knowledge obsolescence is one determinant of how fast and slow patent approval affect profits. This is the rate at which new technologies emerge on the market and displace 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 technical knowledge will lose its value to the producers; the associated patent will lose its value to the inventor. So, higher rate of technical knowledge obsolescence will correspond to shorter effective patent life, expediting the mortality of patents. More specifically, we aggregate the renewal decisions for patents that are in the same technology fields to proxy for the rate of technical knowledge obsolescence. For patent i that is filed in year t, we can denote the technology fields 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 the grant or 0 otherwise. Suppose there is a total of Q patents that are filed in year t. With these

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

notations, we define the technology level rate of obsolescence for technology j and cohort t as:

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

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 technical knowledge obsolescence. The above definition treats each patent as a separate patent in each of its technology fields. In my empirical analysis, I calculate the rates of technical knowledge obsolescence (m=4) in the United States, Germany, France and Great Britain during the period 1981-2005. For United States patents, the technology definition follows the United States Patent Classification (USPC-3 digit, 435 distinct classes); for the three European countries, the technology definition follows the International Patent Classification (IPC-4digit, 639 distinct classes). Figure 1 illustrates the trends of development of the above indices in the 4 countries under a more aggregate definition of technology fields defined in Hall, Jaffe and Trajtenberg (2001) (HJT). The six large technology fields are Chemical, Computer&Communication, Drugs&Medical, Electrics&Electronics, Mechanics and Others (which includes miscellaneous technical areas such as Amusement Devices, Apparel and Textile, Furniture, Heating, etc.). Because the HJT definition associates each USPC classification into the six technology fields, the categorization of the European patents are made using a USPC-IPC concordance.

The first observation is the considerable variation in the rate of obsolescence across technology fields. In the US, 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%).[26] 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 had the lowest STD_{jt} but it surpassed Chemical and Drugs&Medical in the following five years. Third, STD_{jt} in different technology fields have similar trends over time.

Table 5 illustrates the changes of STD_{jt} over the period 2000-2005 for United States patents. The technology fields that have the largest decreases in the rate of technical knowledge obsolescence are Leather Manufacturing and Musical Instruments. The technologies which have the highest increase in developments are Beds, Books and Amusement Device. The fields that remain relatively stable include X-ray, Drug and Organic compounds. It is interesting to notice that the most volatile changes in

[26] In the United States, software patents are extremely valuable although product-cycle for software rarely goes beyond five years (Graham and Mowrey 2004). This does not concern me because I am proxying the **changes** in technical knowledge obsolescence over time and within the same technology field, based on the **changes** in the effective patent rights for a given age of patents.

STD_{jt} occur 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.

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

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

that is, the mean rate of technology obsolescence for patent i filed in year t is a summation of the technical knowledge measurement, weighted by the patent's technology fields. In the empirical analysis, I take into account that, when a patent application is filed, the applicant can only observe the past rate of technical knowledge obsolescence. So, for each patent, I further demean the measure by a three-year average of $MeanSTD_{it}$ in the previous periods of the patent's application date (shown specifically in the section describing my econometric model).

Bilir (2013) has proposed to use mean forward citation lag to measure the length of product (technology) lifecycle.[27] While the "citation lag" measure has the advantage that it exploits relative information throughout a patent's lifetime, it also has the disadvantage of a truncation problem, as a significant portion of citations appear 5 years after the 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 idea that innovations covered by the previous patent are superseded by the innovations covered in a patent. Conceptually, therefore, the "renewal" measure is more closely related to the rate of technical knowledge obsolescence. Another advantage of the "renewal" measure is that I categorize the technology fields at a much smaller cluster and allow the measure to vary over cohorts. Nevertheless, I also compare estimates of my regression based on Bilir's measure using mean citation lag and find consistent results.[28]

[27] She mainly uses the term product cycle, with occasional use of technology cycle. Her measures, however, are based on the idea of technical obsolescence.

[28] The citation lag measure I use is also defined at the USPC 3-digit level and is allowed to vary over cohorts. Results are not shown in this paper.

5 Data Description and Summary Statistics

To empirically evaluate the propositions presented in the theoretical model, I need measures for the rate of technical knowledge obsolescence and patent information for innovations filed in the U.S, China and Europe. I test the same set of hypotheses using two different datasets: inventions that sought patent protection in both China and the US (SIPO-USPTO patent dyads) and inventions that sought patent protection in both China and Europe (SIPO-EPO patent dyads). In either of these datasets, because protection is applied for in both China and another system (the US or EPO), I can observe whether the firm is applying for a Chinese invention patent or a Chinese utility model. I then link this choice with a measure of technical knowledge obsolescence. I describe the method of creating measures and data selection criteria below.

I combine information from several datasets: patent data published by SIPO 1985-2012, patent information from the USPTO website, Harvard Patent Dataverse and EPO Worldwide Patent Statistical Database (PATSTAT). Both SIPO-USPTO and SIPO-EPO patent dyads can be identified using the "priority number" information from each US and EPO patent and matching it to the priority application number of the Chinese patent in the dyad.[29] 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 US patents. In addition, I use the USPTO website to extract all the USPC classifications for each US patent. Because Chinese utility model patents can only protect industrial product innovation while invention patents 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," or "method." For product innovation, the key words are "product," "structure," or "device". I also identify the types of patentee (including firms, public research institutes and individual) through a keyword matching method, and exclude non-firm patentees from the data.

Table 6 provides summary statistics of the SIPO-USPTO patent dyad dataset for all variables used in regressions. Every observation in the dataset consists of a patent application in China and a patent application in the US for the same invention during the period 2001 to 2006. The sample is decomposed into two groups: inventions for which application is made for both a Chinese invention patent and a US patent (77% of the sample) and inventions for which application is made for both a Chinese utility model and a US patent (23% of the sample). As of 2014, 28% of US patent applications were granted

[29]Foreign applicants seeking patent protection in China selected the utility model patent in only 88 cases during the period 1985-2012. So I only include Chinese firms filing patents in both China and the the US (EPO).

while the rest are either rejected or still under examination. 28.86% of Chinese invention patents in this sample were granted US patents; 27.75% of Chinese utility models were granted US patents. 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 an invention patent portfolio larger than 50 prior to the patent they filed in both China and the US, with the largest assignee having 1681 invention patents.

In Table 2, I further decompose the two groups of patents into 6 HJT technology classifications defined by their main USPC. As shown, the percentage of Chinese utility model patents varies significantly across different technologies. In Electrics & Electronics, Mechanical and Others, the percentage of U.S. patents with Chinese utility model priority ranges from 40 % to 60 %. In contrast, in Chemicals, Computer & Communication and Drugs & Medicals, less than 15 % inventions were filed under the utility model. Clearly shown, the choice of IP protection varies across technology fields.

Two limitations of the datasets need to be addressed. One disadvantage of the SIPO patent dataset is that it does not show the length of each patent application document, which affects the cost of applying for a patent. As mentioned above, one of advantage of the Chinese utility model is the relatively low cost of application and maintenance. The application cost largely consists of an attorney to prepare patent applications. Interviews with law firms reveal that the number of words in each application is a proxy variable for the legal cost. For example, one lawyer from *Tee&Howe* told us that they charge 220 rmb ($34) per 100 Chinese characters, as of 2013.[30] 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 much other content of patents, so a simple word count of the entire file does not give us the exact number of words in the patent application.

The second limitation is that 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 sales above five million rmb. Matching the NBS data with our patent dyads would eliminate almost 70% of our patent observations because most patent dyads

[30]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 the SIPO website.

are not filed by large firms. For this reason, we decided to incorporate only one firm level variable, the size of patent portfolio prior to the patent application.

Because economy and technology growth might induce changes in patent law and, in turn, influence firms' patenting strategies, we specifically select our sample in the period 2001-2006 during which there were no changes to codified Chinese patent law.[31] Failure to control for institutional changes in patent regime could lead us to severely biased estimates.

6 Econometric model and Identification

6.1 Estimating Equations

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 the utility model more favorable. This result motivates an estimating equation of the following form:

$$D(UM_{iklt}) = \beta + \beta_1 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} + \Gamma \cdot X_i + \alpha_l * \theta_t + \sum_{j=1}^{n} S_j^{it} + \lambda_k + \epsilon_{iklt} \quad (9)$$

where $D(UM_{iklt})$ is a dummy variable that equals one if the applicant has chosen the utility model in China for patent i of firm k located in province l during year t. Because each patent i belongs to multiple technology fields defined by $(S_1^{it}, S_2^{it}, S_3^{it}, ...S_n^{it})$, the technology fixed effects, $\sum_{j=1}^{n} S_j^{it}$ control for each technology field in which the patent is defined. $\frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3}$ is defined as the average percentage of patents that are given up within four years from issue date for all patents (either U.S. or European) 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 the utility model might have significantly lower technical quality compared to those under invention patents because no examination is required. To control for this issue, I add in a variable *Grant* which measures whether the US or EPO patent is granted. I also add in patent level variables at the application date to further control for patent quality variations. Consistent with the previous literature, these controls include the number of patent claims, number of inventors (Chinese and foreign inventors are treated equally), and number of assignees (Lanjouw and Schankerman 2004). Previous literature has pointed out that the number of countries in which an application is filed is positively correlated with the quality of patent (Putnam 1997). Because our data already includes

[31]See section 2.1 for a brief introduction to the three Chinese patent law amendments which happened in 1993, 2000 and 2008, respectively.

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 either directly, through filing in the designated country or countries , or through the Patent Cooperation Treaty (PCT) route. Because different routes might reflect applicants' heterogeneous motives for patenting, it is important to control for this variable.

Because firms treat patents as strategic assets, one would expect their patent strategies to be correlated with other firm-level characteristics. Strategic patenting is found to be most common in the group of "experienced patent filers" (Kortum and Lerner 1998) and R&D intensive firms (Hall and Ziedonis 2001). However, our data prevent us from adding any variable that is related to the firm's financial performance (such as R&D investment). Nevertheless, we control for the size of the patent portfolio prior to the application date of the observation and for firm fixed effects to account for unobservable characteristics that are fixed over time. Starting in 1995, many provinces in China implemented patent subsidy and tax deduction policies as a response the central government's theme of "indigenous innovation."[32] Since these policies have a direct effect on patenting behaviors, I add in interactions of province and year, $\alpha_l * \theta_t$ to fully control for any concurrent policy changes that are likely to bias our estimates.

The main coefficient of interest, β_1, captures the influence of technical knowledge obsolescence on patenting behavior. According to the model, where $\beta_1 > 0$ indicates that the firm is in a fast-developing field, applicants should have a higher propensity of selecting utility model patents.

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

$$\begin{aligned} D(UM_{iklt}) \quad &= \beta + \beta_1 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} + \beta_2 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} \cdot \frac{\sum_{z=t-3}^{t-1} MeanGrantlag_{iz}}{3} \\ &+ \beta_3 \cdot \frac{\sum_{z=t-3}^{t-1} MeanGrantlag_{iz}}{3} + \Gamma \cdot X_i + \alpha_l * \theta_t + \sum_{j=1}^{n} S_j^{it} + \lambda_k + \epsilon_{iklt} \end{aligned} \tag{10}$$

where the new variable $\frac{\sum_{z=t-3}^{t-1} MeanGrantlag_{iz}}{3}$ is the cohort-technology level average grant lag of invention patent examination delay in the three years before the patent application for the observation. Each component under the summation, $MeanGrantlag_{it}$, is a sum of average invention patent grant lags

[32] According to our own collection of information, we find at least nine provinces in China have adopted some form of patent subsidy and/or tax deduction policies by 2011. These provinces include Guangdong, Liaoneng, Jilin, Hubei, Shanghai, Beijing, Anhui, Jiangxi and Tianjin.

in technology fields, weighted by the technology presence of patent i, $(S_1^{it}, S_2^{it}, S_3^{it}, ...S_n^{it})$. Smaller $MeanGrantLag_{it}$ indicates a higher speed of invention patent examination and a reduced advantage associated with utility model patents. According to the model, applicants should be less sensitive to technology obsolescence changes for smaller $MeanGrantLag_{it}$ compared to larger $MeanGrantLag_{it}$. This corresponds to $\beta_2 > 0$.

Proposition 3 states that applicants' heterogeneity of patent portfolio size affects their patent choice responses to changes in technical knowledge obsolescence. An applicant with a larger patent portfolio 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 the invention patent or the low enforcement strength and short protection term of the utility model. Empirically, we estimate the following specification:

$$\begin{aligned} D(UM_{iklt}) \; &= \beta + \beta_1 \cdot \tfrac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} + \beta_2 \cdot \tfrac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} * PatentStock_{kt-1} \\ &+\beta_3 \cdot PatentStock_{kt-1} + \Gamma \cdot X_i + \alpha_l * \theta_t + \textstyle\sum_{j=1}^{n} S_j^{it} + \lambda_k + \epsilon_{iklt} \end{aligned} \quad (11)$$

where $Portfolio_{kt-1}$ is the size of patent portfolio (e.g. total number of invention patents previous to the application year of the observation) in firm k in period $t-1$. *Proposition* 3 corresponds to $\beta_3 < 0$.

6.2 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 (Mansfield 1986). Patents have been perceived to be most effective in pharmaceuticals; their effectiveness varies in other technology areas, noticeably Electrics and Electronics. Because 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 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 that include both technology and firm fixed effects with regressions only including technology fixed effects.

Patent strategies are likely to be influenced by other economic variables, such as the market structure. Therefore, when a new or superior technology is introduced, it is likely to influence firms' patenting decisions, either directly, as described in our theory, or indirectly, through its influence on market structure. To mitigate this concern, we specifically choose our measure of technical knowledge obsolescence to be calculated based on patents in foreign countries. This is because technological progress in foreign countries is unlikely to directly influence on the market structure in the domestic country.

7 Main Results

7.1 Rate of Technical Knowledge Obsolescence and Patenting Choice

Because the dependent variable is a dummy, a probit model is used.[33] I cluster the standard errors either at the main technology field or at the firm level, depending on whether the econometric specification includes a firm fixed effect. Estimates of (9) appear in Table 7. The results are strongly consistent with *Proposition* 1 in the theoretical model. In column 1, I find evidence that, when technical knowledge obsolescence becomes larger, firms have a higher propensity to choose the utility model to protect their inventions. In addition, the variable *Grant* is not significantly correlated with an applicant's patenting choice. This result supports the validity of our sample selection criteria, i.e., that the *ex ante* technical quality of the inventions is not systematically differentiated between the Chinese invention patent group and the utility model group. In column 2, I add in patent level variables to further control for potential patent quality differences and find that the influence of the rate of technical knowledge obsolescence remains nearly identical. The point estimates of β_1 (6.0868 in column 1 and 5.9870 in column 2) correspond to a marginal effect of a 133% increase in the propensity of filing under the utility model (calculated using results from column 2). More specifically, a one standard deviation increase in the rate of technical knowledge obsolescence will result in a 7.6% increase in the propensity to file utility models in the coming year. In column 3, firm fixed effects are added and patent applicants that have filed only once during the period 2001-2006 are dropped. In this case, the point estimate can be interpreted as the effect of technical knowledge obsolescence on patent choices at the firm level. Comparing point estimates in column 2 and 3, I find that the one in column 3 is 80% larger. The increase in the point estimate of β_1 after controlling for firm dummies shows that the influence of technology obsolescence is not mainly driven by entry of new firms but rather by changes in the economic behavior of existing firms.

[33] I also compare my results with estimates using OLS and logit, and the results are similar.

7.2 Heterogeneity: SIPO Administration Dynamics

Table 8 provides estimates corresponding to *Proposition* 2. Regression results are consistent with the theoretical model. The significant drop in the number of observations (e.g. in column 1, the original sample includes 4712 observations, now only 2582) after controlling from $MeanGrantlag_{it}$ is due to the imperfect match between USPC and IPC.[34] Nevertheless, $MeanSTD_{it}$ are still significant in columns 1 and 3 and are not very different from results in the previous table. The key estimate of interest, β_2 in (10), 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 the rate of technical knowledge obsolescence when SIPO's overall efficiency in examining invention patent decreases. In column (4), the marginal effects of β_1 and β_2 are -11.61 and 0.0077, respectively. At the 25^{th} percentile and 75^{th} percentile of $MeanGrantlag_{it}$ (1578 days and 1731 days), a one standard deviation increase in the rate of technology obsolescence will increase patent applicants' propensity for filing the utility model by 3.0% and 9.4%, respectively. At the mean rate of technology obsolescence (0.1457), a one standard deviation increase in the examination delay at SIPO (147 days) will increase the propensity to file for the utility model by 16.49%. At SIPO's mean examination delay (1672 days), this estimate corresponds to a grant lag elasticity of demand of 2.82 for the utility model, which means that, if there is a 6 months increase in grant lag for invention patents, about 10% more applications are willing to switch from filing for an invention patent to filing for a utility model, a significant change. Given that an examiner's effort for each patent application is relatively limited (Farrell and Shapiro 2008), a decrease in PTO's examination efficiency has a significant impact on the effectiveness of the invention patent.

7.3 Strategic Patenting: Applicant's Patent Portfolio Size

To evaluate *Proposition* 3, we investigate the effect of technical knowledge 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 (11) for all applicants and also estimate variants of (11) separately for large portfolio size applicants and small portfolio size applicants. Firm fixed effects are included to control for applicant level unobservables that do not change over time. The results (Table 9) show that small portfolio holders are more sensitive than large portfolio holders to changes in the rate of technical knowledge obsolescence, which is consistent with the theoretical model that a large portfolio holder is more capable of circumventing the ineffectiveness of invention patent and utility models by utilizing other patents in his pool. In fact, results in columns 1-2 show that large portfolio holders do not respond to changes in technical

[34] E.g. in the US there is a class named G9B after 1980, but there is no corresponding IPC class.

knowledge obsolescence.

7.4 Subsample estimations

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

$$\begin{aligned} D(UM_{iklt}) \quad &= \beta + \beta_1 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} + \beta_2 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} * MediumSTD \\ &+ \beta_3 \cdot \frac{\sum_{z=t-3}^{t-1} MeanSTD_{iz}(4)}{3} \cdot LowSTD + \Gamma \cdot X_i + \alpha_l * \theta_t + \sum_{j=1}^{n} S_j^{it} + \epsilon_{iklt} \end{aligned} \quad (12)$$

Table 10 provides regression results for (11). Comparing columns (1)-(3), the applicant's patent choice is significantly influenced by changes in $MeanSTD_{ijt}$ only in the group with the highest rates of technical knowledge obsolescence. As the rate of technology obsolescence decreases, not only do the estimated coefficients become smaller but they also become statistically insignificant. These results offer further support to our theoretical model: the advantage of fast protection is more salient when the rate of technical knowledge obsolescence is relatively high.

8 Robustness checks with SIPO-EPO patent dyads

While our theoretical results relate individual applicant's patenting strategies to a measure of how quickly new technologies are introduced, we test our hypotheses based on SIPO-USPTO patent dyads and calculate technical knowledge obsolescence measures using only United States patent data. One of the unique features about the United States patent system is that it allows patent applicants to file continuations. Even if the patent examiner concludes that an invention is patentable, the applicant can still abandon the right an infinite amount of times and start the process over again. This institutional design makes it more flexible for patent applicants to manipulate patent pendency to their advantage and has the result that 90% of US patent applications are granted eventually (Quillen and Webster 2001). Based on the high grant rate of US patent, one would expect that many weak patents, inventions that would not be granted patent rights under stringent examination, are allowed by the USPTO (Farrell and Shapiro 2008). If there is a large variation in the technical quality of US patents, then the renewal measures I am using could both capture the changes in technology as well as changes in patent quality. I address these concerns in two steps. First, I change the country for creating measures of technical knowledge obsolescence to three European countries, namely, Germany, France and Great

Britain, in which patent applicants are much more restricted (compared to the US) in their flexibility to delay patent issue. Second, instead of using the entire patent pool within one country, I use only the EPO granted patents that are designated to the country. This careful selection has two advantages: first, the European Patent Office sets a uniform and stringent patentability standard.[35] Patents issued by EPO are presumably high in terms of technical quality. Second, previous studies have shown that the patent quality is positively correlated with the number of countries applied to. Filing a EPO patent reflects the applicant's intention to secure patent protections in multiple European countries. So the EPO patent should be considered as the "top tier" patent within one country. In other words, the changes in the renewal behaviors over time for EPO patents should primarily reflect applicants' concern for technology upgrading and turnovers.

Following the above strategy, we conduct our analysis using SIPO-EPO patent dyads and calculate three alternative measures of technical knowledge obsolescence based on EPO patent data designated to the following three European countries: Germany, France and Great Britain, respectively.

Table 11-13 report results for model (9) and provide confirmation for *proposition* 1. Estimates in columns 1-3 reveal a qualitatively similar pattern of sensitivity to technology change compared to columns 1-3 in Table 7. For the SIPO-EPO patent sample, a one standard deviation increase in rate of technical knowledge obsolescence increases the propensity to file for the utility model by 8.28%, 6.76% and 10.04%, using the Germany, France and Great Britain EPO patents as obsolescence measures, respectively (using the point estimates from column (3) of Table 11-13). Given that the SIPO-USPTO counterpart is 7.6%, we find the sensitivities of patent choice with respect to rate of technical knowledge obsolescence, estimated using different $MeanSTD_{it}$, measured based on four countries, US, Germany, France and Great Britain are closely comparable with each other, with similar significance.

Tables 14-16 reports results for *Proposition 2*. Consistent with the results shown in Table 8, we also find that an increase in the examination efficiency of SIPO's invention patents results in a decrease in sensitivity of patent choices with respect to technical knowledge obsolescence, measured using EPO patent dataset.

Table 17 reports results for *Proposition 3*. In columns (1) - (6), although the point estimates of the key variable $MeanSTD_{it} * LargePatentPortfolio_{it-1}$ are always negative, they are not statistically

[35] A comparative study of the inventive step standards in the European, Japanese and United States patent offices show that grant rates at EPO, JPO and USPTO (without counting continuation) are 55%, 49% and 54%, respectively. See www.aspi.asso.fr/attachment/297907/ for more information.

significant (except in column (5)). We, therefore, are not able to find support for *Proposition 3* in the EPO dataset.

9 Conclusion

In this paper, we provide theoretical and empirical analysis of how firms' optimal patent choice is influenced by changes in the rate of technical knowledge 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 and slow patent protections. The model indicates that the tradeoff is influenced by changes in the rate of technical knowledge obsolescence, a measure we create to proxy for the speed of technology development. Firms' propensity of choosing a fast patent increases as technology develops faster; this response becomes very salient in technology fields that have especially fast technology upgrading.

Our empirical results are strongly consistent with our theoretical model. In technology fields where the rates of technical knowledge obsolescence increase over time, we find subsequent patent applicants' propensity of choosing the utility model also increases significantly. Although the utility model is inferior to the invention patent due to shorter protection periods and narrower patent scope, interactions between rate of technology obsolescence and SIPO's average grant lag explain that the choice between the invention patent and the utility model is mainly due to whether applicants need fast protection. The results provide evidence that the 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 has argued that a uniform patent system might be unable to satisfy the heterogeneous demands for patent protection. With the patent attributes fixed, the system tends to over-reward some inventors 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 that 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 imply a potential welfare enhancement: because weaker patents create lesser per-period distortion 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.

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10 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 $(0, +\infty)$:

$$\begin{aligned} \frac{dK(\rho, T_1)}{d\rho}|_{(0,+\infty)} &= -\int_{t_1}^{t_2} se^{-rs}(b_2\pi - c)ds + \int_{T_2}^{+\infty} se^{-rs}(b_1\pi - c)ds \\ &> -\int_{t_1}^{t_2} t_2e^{-rs}(b_1\pi - c)ds + \int_{T_2}^{+\infty} T_2e^{-rs}(b_1\pi - c)ds > 0 \end{aligned}$$

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. $\Pi_2 = \Pi_1$

$$
\begin{aligned}
\frac{d(\Pi_2-\Pi_1)}{d\rho} &= -\int_{t_2}^{t_1} se^{-(r+\rho)s}b_2\pi ds + \int_{t_1}^{\frac{1}{\rho}log\frac{b_2\pi}{c}} se^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{\frac{1}{\rho}log\frac{b_2\pi}{c}}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} se^{-(r+\rho)s}b_1\pi ds \\
&+\frac{1}{\rho^2}log\frac{b_2\pi}{c}(\frac{b_2\pi}{c})^{-\frac{r}{\rho}}\frac{b_1-b_2}{b_2}c + \frac{1}{\rho^2}log\frac{b_1\pi}{c}(\frac{b_1\pi}{c})^{-\frac{r}{\rho}}(\frac{b_1}{b_1}c-c) - \frac{1}{\rho^2}log\frac{b_2\pi}{c}(\frac{b_2\pi}{c})^{-\frac{r}{\rho}}(\frac{b_1}{b_2}c-c) \\
&> -\int_{t_2}^{t_1} t_1e^{-(r+\rho)s}b_1\pi ds + \int_{t_1}^{\frac{1}{\rho}log\frac{b_2\pi}{c}} t_1e^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{\frac{1}{\rho}log\frac{b_2\pi}{c}}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} t_1e^{-(r+\rho)s}b_1\pi ds \\
&= b_1\pi t_1\cdot(e^{-\frac{r+\rho}{\rho}\cdot log\frac{b_2\pi}{c}} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho}\cdot log\frac{b_1\pi}{c}}) \\
&> b_1\pi t_1\cdot(\frac{b_2\pi}{c}^{-(\frac{rt_1}{logb_1\pi-logc})+1} - \frac{b_1\pi}{c}^{-(\frac{rt_1}{logb_1\pi-c})+1} + e^{-(rt_1+logb_1\pi-logc)} - e^{-(rt_2+\frac{t_2}{T_1}(logb_1\pi-logc))}) > 0 > 0
\end{aligned}
$$

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:

$$
\begin{aligned}
\frac{d(\Pi_2-\Pi_1)}{d\rho} &= -\int_{t_2}^{t_1} se^{-(r+\rho)s}b_2\pi ds + \int_{t_1}^{T_2} se^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{T_2}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} se^{-(r+\rho)s}b_1\pi ds \\
&+\frac{1}{\rho^2}log\frac{b_1\pi}{c}(\frac{b_1\pi}{c})^{-\frac{r}{\rho}}(\frac{b_1}{b_1}c-c) \\
&> -\int_{t_2}^{t_1} t_1e^{-(r+\rho)s}b_1\pi ds + \int_{t_1}^{T_2} t_1e^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{T_2}^{\frac{1}{\rho}log\frac{b_1\pi}{c}} t_1e^{-(r+\rho)s}b_1\pi ds \\
&= b_1\pi t_1\cdot(e^{-(r+\rho)T_2} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho}\cdot log\frac{b_1\pi}{c}}) \\
&> b_1\pi t_1\cdot(e^{-\frac{r+\rho}{\rho}\cdot log\frac{b_2\pi}{c}} + e^{-(r+\rho)t_1} - e^{-(r+\rho)t_2} - e^{-\frac{r+\rho}{\rho}\cdot log\frac{b_1\pi}{c}}) \\
&> b_1\pi t_1\cdot(\frac{b_2\pi}{c}^{-(\frac{rt_1}{logb_1\pi-logc})+1} - \frac{b_1\pi}{c}^{-(\frac{rt_1}{logb_1\pi-c})+1} + e^{-(rt_1+logb_1\pi-logc)} - e^{-(rt_2+\frac{t_2}{T_1}(logb_1\pi-logc))}) > 0 > 0
\end{aligned}
$$

where the 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:

$$\frac{d(\Pi_2-\Pi_1)}{d\rho} = -\int_{t_2}^{t_1} se^{-(r+\rho)s}b_2\pi ds + \int_{t_1}^{T_2} se^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{T_2}^{T_1} se^{-(r+\rho)s}b_1\pi ds$$
$$> -\int_{t_2}^{t_1} t_1e^{-(r+\rho)s}b_2\pi ds + \int_{t_1}^{T_2} t_1e^{-(r+\rho)s}(b_1-b_2)\pi ds + \int_{T_2}^{T_1} t_1e^{-(r+\rho)s}b_1\pi ds$$
$$= t_1((\Pi_1-\Pi_2) + \frac{1}{r}(e^{-rT_2} - e^{-rT_1} - e^{-rt_2} + e^{-rt_1})$$
$$= t_1 \cdot ((\Pi_1-\Pi_2) - \frac{1}{r}K(0,T_1)) > 0$$

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.

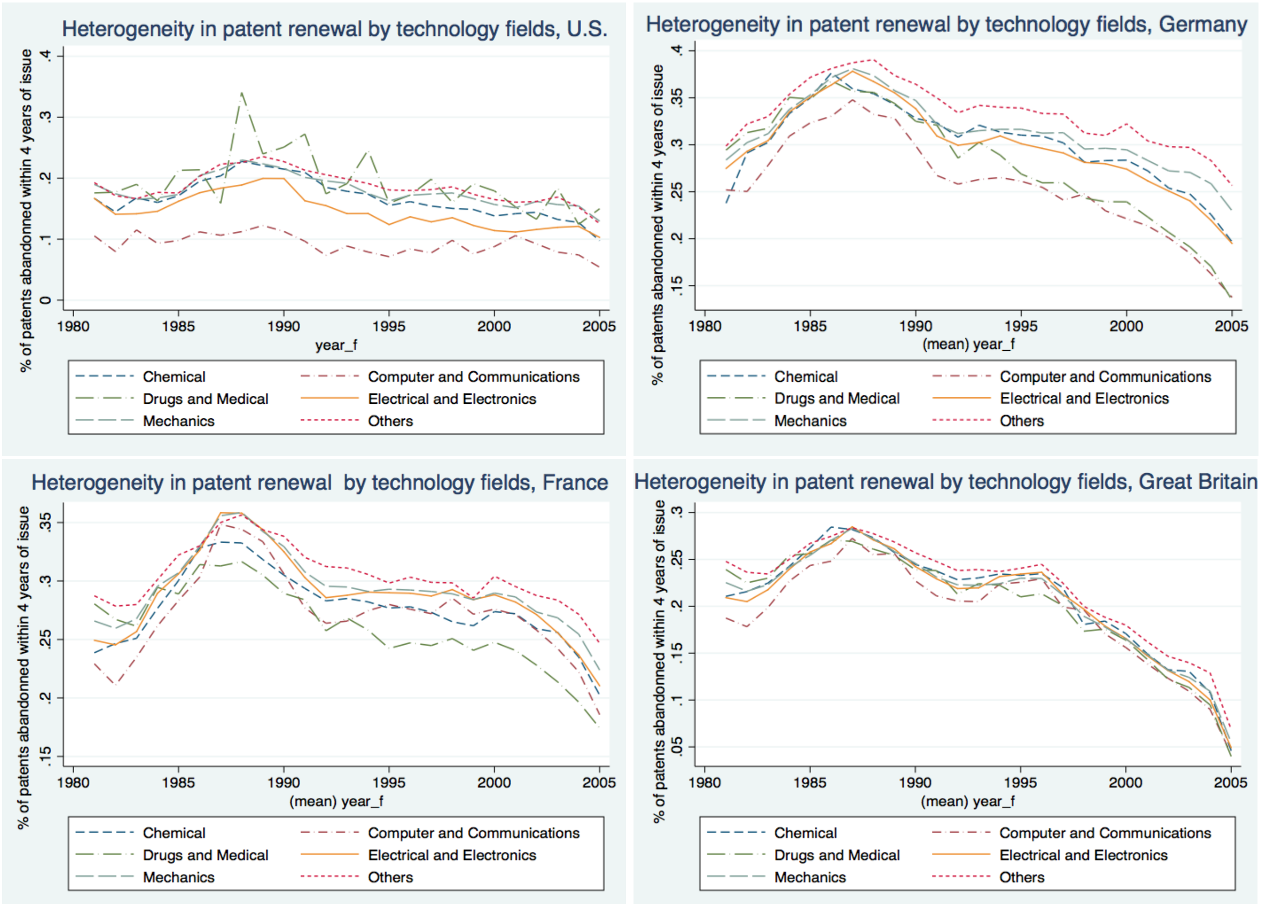

Figure 1: Heterogeneity in Patent Renewal Behaviors by Technology Fields: US, Germany, France and Great Britain

Notes: These 4 figures plot the time trend of the percentages of ineffective patent rights (within 4 years of patent issue) for all granted US (EPO) patents filed in the same year and the same technology. Data sources include USPTO patent dataset and EPO Worldwide Patent Statistical Database April 2011. The technology classification used here is defined in Hall, Jaffe, and Trajtenberg (2001). The definition categorizes patents into six big technology fields Chemical, Computer and Communications, Drugs and Medical, Electrical and Electronics, Mechanics and Others based on their primary 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.

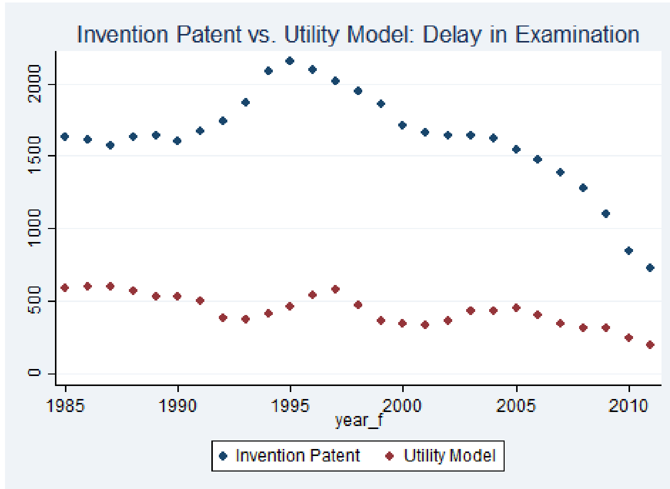

Figure 2: Invention Patent vs. Utility Model: delay in patent grant (day), 1985-2011

Notes: This figure plots the annual average patent pendency for Chinese invention patents and Chinese utility models over the period 1985-2011. Mean grant lags (measured in days) for Chinese invention patents and Chinese utility models are estimated using SIPO patent dataset.

Table 1: Invention Patent *vs.* Utility Model in China

	Invention Patent	Utility Model
Definition	Any new technical solution or improvement relating to a product or a process.	Any new technical solution or improvement relating to the shape, structure or their combination of a product.
Subject Matter	process and product innovations	product innovations
Patentability	substantial examination of novelty, non-obviousness and utility.	No substantial examination of novelty and non-obviousness.
Average Grant Lag	54 months	14 months
Term	20 years	10 years
Application (YMB):	950	500
Examination (YMB):	2500	N/A
Attorney fee (YMB):	4000-10000	2500-6000
Maintenance Fees (YMB) (annual renewal schedule)	900, $1^{st} - 3^{rd}$ years; 1200, $4^{th} - 6^{th}$ years; 2000, $7^{th} - 9^{th}$ years; 4000, $10^{th} - 12^{th}$ years; 6000, $13^{th} - 15^{th}$ years; 8000, $16^{th} - 20^{th}$ years;	600 $1^{st} - 3^{rd}$ years 900 $4^{th} - 5^{th}$ years 1200 $6^{th} - 8^{rth}$ years 2000 $9^{th} - 10^{th}$ years

Notes: This table shows differences between Chinese invention patents and Chinese utility models with respect to their provisions, application and maintenance costs. Average grant lags for invention patents and utility models are estimated using SIPO patent dataset 1985-2011. The costs of patent application and renewal are obtained from SIPO website at www.sipo.gov.cn. For attorney fees, we interviewed several lawyers from different law firms located in Beijing and Hongkong, China. We asked for the attorney fees they charge for invention patents and utility models, respectively. In general, law firms charge the same rate regardless of the locations of their clients.

Table 2: Distribution of Chinese Invention Patents and Chinese Utility Models 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%

Notes: This table shows the distribution of Chinese invention patents and Chinese utility models in different technology fields. The dataset is consist of inventions that are sought for patent protections both in China and the United States (SIPO-USPTO patent dyads) during the period 2001-2006. Each observation represents an invention that is filed either for a Chinese invention patent and a US patent or a Chinese utility model and a US patent. The table shows a decomposition of the two groups of patents into six technology fields. The technology classification used here is defined in Hall, Jaffe, and Trajtenberg (2001). The definition categorizes patents into six big technology fields Chemical, Computer and Communications, Drugs and Medical, Electrical and Electronics, Mechanics and Others based on their primary 3-digit United States Patent Classification (USPC).

Table 3: Changes in the Rate of Technical Knowledge Obsolescence 2000-2005 (3-digit USPC)

Technology Fields	Rank	USPC	Changes in STD_{jt}
Biggest decrease in rate of technical knowledge 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 changes in rate of technical knowledge obsolescence			
X-ray or gamma ray system	216	378	-0.01%
Metal Fusion bonding	217	228	-0.01%
Drug, bio affecting and body treating	218	424	0
Organic Compound	219	536	0.05%
Fuel and related composition	220	44	0.08%
Biggest increase in rate of technical knowledge obsolescence			
Bath, Closets, Sink, Spittoons	431	4	15.91%
Special Receptacle or Package	432	206	16.66%
Amusement Device: Game	433	273	26.79%
Books, Strips and Leaves for manifolding	434	462	30.78%
Beds	435	5	46.74%

Note: This table shows the changes in the rate of technical knowledge obsolescence. For each distinct technology field defined by 3-digit United States Patent Classification (USPC), we calculate the difference between the rate of obsolescence for year 2005 and that for 2000. We then rank these differences based on their relative size. There are a total of 435 distinct technology fields. All patents used were filed at USPTO during the fiscal years 2000- 2005 and granted by 2014. STD_{jt} is our measure of technical knowledge obsolescence. It is defined as the percentage of patents filed in year t and technology field j that are abandoned within 4 years after issue.

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
Grant in U.S. (Invention Patent)	0.2886	0.4531	0	1
Grant in U.S. (Utility Model)	0.2724	0.4453	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	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
Duel-Application (238)	0.0396	0.1950	0	1
Applicant Nationality (1 Domestic; 0 Foreign)	0.8208	0.3834	0	1
Innovation Type (1 Product; 2 Process; 3 Both)	2,980	901	2,327	
Technology Information:				
Rate of Technical Knowledge Obsolescence	0.1262	0.0547	0.0318	0.3469
Number of Technology fields: 344				
Assignee Information:				
Invention Patent Portfolio Size	14.8011	80.5061	0	1239
Number of Distinct Assignee	1,791			
Others:				
Number of Patents	6,208			

Note: This table summarizes the regression variables. The dataset is consist of inventions sought for patent protections both in China and the US during the period 2001-2006. Patent attributes are from Harvard Patent Dataverse and SIPO patent dataset 1985-2011. Rate of Technical knowledge Obsolescence is calculated using all USPTO patents filed between 1998-2005. Duel-Application indicates the invention has be sought protection under both Chinese invention patent and Chinese utility model in China. Application Nationality: 0/1 dummy, 1 corresponds to Chinese patent applicant and 0 corresponds to non-Chinese patent applicant. Innovation Type: 1. product innovation. 2. process innovation. 3. innovation describing both a process and product technology improvement.

Table 5: Estimations of Technical Knowledge Obsolescence on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all USPTO patent applications with Chinese Priority. (Dep. Var = Dummy equals one if applied for **utility model**, Mean=0.236 for all USPTO patent applications. Rates of Technical Knowledge Obsolescence are calculated using all USPTO patents applied during 1998-2005.)

	(1)	(2)	(3)
Mean STD_{iz} (*weighted USPC*)	6.0868	5.9870	10.0669
(*averaged over periods t, t-1, t-2*)	(2.2502)***	(2.1294)***	(4.339)***
Grant	-0.1019	-0.018	0.1485
	(0.8712)	(0.0719)	(0.8676)*
Patent Portfolio Size		0.001	0.0004
		(0.0004)**	(0.0002)**
Number of Claims		-0.0154	-0.1265
		(0.004)***	(0.0092)
Number of Inventor		-0.1154	0.007
		(0.0313)***	(0.0078)
Number of Assignee		-1.013	-0.6463
		(0.2351)***	(0.4336)
Continuation Dummy		0.1189	-0.0211
		(0.1333)	(0.1801)
PCT Filing Dummy		-0.3241	0.0879
		(0.0852)	(0.1525)
Patent Characteristics	No	Yes	Yes
Cohort * Province Dummies	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes
Firm Dummies	No	No	Yes
N	4712	4712	2310
Log PseudoLH	-1944.9714	-1868.3764	-867.6572
Pseudo R^2	0.3437	0.3696	0.4444

Notes: Patent-Level Observation. All estimates are from probit models. The sample includes United States Patent and Trademark Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors are shown in parentheses. In columns (1) and (2), standard errors are clustered at each patent's primary United States Patent Classification (USPC). In column (3), standard errors are clustered at firm level. *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$, 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 weighted over the technology presence of the observed patent. *Grant* is a dummy variable that equals to one if the US patent application is granted by 2014. *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. *Cohort * Province Dummies*: 0/1 indicator variable for application year*province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 435 distinct USPC fields).

Table 6: Estimations of Rate of Technical Knowledge Obsolescence and SIPO Invention Patent Administrative Dynamics on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all USPTO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**. Mean=0.236 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_{iz} (*weighted USPC*)	4.2885	-48.2041	5.2669	-51.1986	-4.8496	-150.6912
(*averaged over periods t, t-1, t-2*)	(2.3474)*	(25.0674)***	(2.337)**	(24.7140)**	(6.3571)	(67.1555)**
Mean $Grantlag_{iz}$	-0.0004	-0.0045	0.0001	-0.0042	-0.0005	-0.0111
(*averaged over periods t, t-1, t-2*)	(0.0007)	(0.0021)**	(0.0007)	(0.0020)**	(0.0017)	(0.0043)**
Mean STD_{iz} * *Mean* $Grantlag_{iz}$		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
Cohort * Province Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm 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 probit models. The sample includes United States Patent and Trademark Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors are shown in parentheses. In columns (1) to (4), standard errors are clustered at each patent's primary United States Patent Classification (USPC). In columns (5) and (6), standard errors are clustered at firm level. *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$, 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 weighted over the technology presence of the observed patent. $MeanGrantlag_{iz}$, is the average grant lag for all Chinese invention patents that are filed in the past 3 years and weighted over the technology presence of the observed patent. *Grant* is a dummy variable that equals to one if the US patent application is granted by 2014. *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. *Cohort * Province Dummies*: 0/1 indicator variable for application year*province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 435 distinct USPC fields).

Table 7: Estimations of Rate of Technical Knowledge Obsolescence and Firms' Patent Portfolio Size on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all USPTO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**. Mean=0.236 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_{iz} (*weighted USPC*)	2.9233	7.1284	7.2000	13.0911	6.1434	10.8983
(*averaged over periods t, t-1, t-2*)	(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_{it} * 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)
Cohort * Province Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology Field Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Firm 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 probit models. The sample includes United States Patent and Trademark Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors are shown in parentheses. In columns (1), (3) and (5), standard errors are clustered at each patent's primary United States Patent Classification (USPC). In columns (2), (4) and (6), standard errors are clustered at firm level. *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$, 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 weighted over the technology presence of the observed patent. *Large Patent Portfolio* is a dummy that equals to one if the firm's stock of invention patent, prior to filing the patent under observation, is greater than the average size of patent portfolio in the sample (14 patents). *Grant* is a dummy variable that equals to one if the US patent application is granted by 2014. *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. *Cohort * Province Dummies*: 0/1 indicator variable for application year*province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 435 distinct USPC fields).

Table 8: Sub-sample estimations of Rate of Technical Knowledge Obsolescence on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all USPTO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**. Mean=0.236 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_{iz} (*weighted USPC*)	45.6376	10.4291	3.6353	24.3402
(*averaged over t, t-1, t-2*)	(22.0143)**	(7.3930)	(4.0569)	(12.2484)**
Mean STD_{iz} * Medium STD_{iz}				-12.7603
				(15.2491)
Mean STD_{iz} * Small STD_{iz}				-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	-0.9865
	(0.2774)***	(0.2247)***	(0.2286)***	(0.2357)***
Continuation Dummy	-0.7243	0.2010	0.1286	-0.1125
	(0.4323)*	(0.2070)	(0.2007)	(0.1051)
PCT Filing Dummy	0.2925	0.1787	-0.1270	-0.3291
	(0.2365)	(0.1558)	(0.1012)***	(0.0626)***
Cohort * Province 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 probit models. The sample includes United States Patent and Trademark Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors are shown in parentheses. Standard errors are clustered at each patent's primary United States Patent Classification (USPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$, 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 weighted over the technology presence of the observed patent. $MediumSTD_{iz}$ and $SmallSTD_{iz}$ are dummies that equal to one if the $MeanSTD_{iz}$ of the patent under observation belongs to the $33^{rd} - 67^{th}$ and smaller than the 33^{rd} quartile of the $MeanSTD_{it}$ distribution, respectively. *Grant* is a dummy variable that equals to one if the US patent application is granted by 2014. *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. *Cohort * Province Dummies*: 0/1 indicator variable for application year*province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 435 distinct USPC fields).

Table 9: Estimations of Rate of Technical Knowledge Obsolescence on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to Germany.)

	(1)	(2)	(3)
Mean STD_{iz} (*weighted IPC*)	11.7544	10.0837	9.6383
(*averaged over periods t, t-1, t-2*)	(2.1319)***	(3.4345)***	(3.4254)***
Grant	-0.0957	-0.0835	-0.0028
	(0.0841)	(0.0955)	(0.0975)
Patent Portfolio Size			0.0007
			(0.0014)
Number of Claims			-0.0300
			(0.0084)***
Number of Inventor			-0.1784
			(0.0785)**
Number of Assignee			-0.1131
			(0.1499)
Continuation Dummy			0.1406
			(0.5388)
Patent Characteristics	No	No	Yes
Cohort* Province Dummies	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes
N	2687	1844	1844
Log PseudoLH	-1222.5284	-648.2480	-630.3783
Pseudo R^2	0.0866	0.359	0.3698

Notes: Patent-Level Observation. All estimates are from probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to Germany) that are filed in the past 3 years and weighted over the technology presence of the observed patent.*Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 10: Estimations of Rate of Technical Knowledge Obsolescence on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to France.)

	(1)	(2)	(3)
Mean STD_{iz} (weighted IPC)	9.2514	6.4675	5.8551
(*averaged over periods t, t-1, t-2*)	(1.1933)***	(2.0833)***	(1.9488)***
Grant	-0.0627	-0.1196	-0.0083
	(0.0811)	(0.0938)	(0.0982)
Patent Portfolio Size			0.0007
			(0.0014)
Number of Claims			-0.0300
			(0.0084)***
Number of Inventor			-0.1875
			(0.0772)**
Number of Assignee			-0.1245
			(0.1502)
Continuation Dummy			0.1589
			(0.5270)
Patent Characteristics	No	No	Yes
Cohort * Province Dummies	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes
N	2687	1844	1844
Log PseudoLH	-1146.8931	-671.4276	-630.3783
Pseudo R^2	0.1431	0.3575	0.3698

Notes: Patent-Level Observation. All estimates are from probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to France) that are filed in the past 3 years and weighted over the technology presence of the observed patent.*Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 11: Estimations of Rate of Technical Knowledge Obsolescence on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to Great Britain.)

	(1)	(2)	(3)
Mean STD_{iz} (*weighted IPC*)	6.1836	6.4434	5.8414
(*averaged over periods t, t-1, t-2*)	(0.7772)***	(1.3446)***	(1.3505)***
Grant	-0.06820	-0.1276	-0.0179
	(0.0755)	(0.0939)	(0.0990)
Patent Portfolio Size			0.0004
			(0.0014)
Number of Claims			-0.0293
			(0.0083)***
Number of Inventor			-0.1942
			(0.0773)**
Number of Assignee			-0.1248
			(0.1523)
Continuation Dummy			0.1663
			(0.5254)
Patent Characteristics	No	No	Yes
Cohort * Province Dummies	Yes	Yes	Yes
Technology Field Dummies	No	Yes	Yes
N	2687	1844	1844
Log PseudoLH	-1121.1503	-660.9236	-621.7800
Pseudo R^2	0.1624	0.3566	0.3784

Notes: Patent-Level Observation. All estimates are from probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to Great Britain) that are filed in the past 3 years and weighted over the technology presence of the observed patent.*Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 12: Estimations of Rate of Technical Knowledge Obsolescence and SIPO Invention Patent Administrative Dynamics on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to Germany.)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{iz} (*weighted IPC*)	11.1553	-9.7103	10.2158	-18.6989	10.3973	-19.3331
(*averaged over periods t, t-1, t-2*)	(1.7224)***	(10.0375)	(3.4086)***	(12.5471)	(3.4471)***	(12.5577)
Mean $Grantlag_{iz}$	-0.0003	-0.0025	-0.0007	-0.0037	-0.0004	-0.0035
(*averaged over periods t, t-1, t-2*)	(0.0004)	(0.0013)*	(0.0005)	(0.0004)	(0.0005)	(0.0014)**
Mean STD_{iz} * *Mean* $Grantlag_{iz}$		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
Cohort*Province 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 probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to Germany) that are filed in the past 3 years and weighted over the technology presence of the observed patent. $MeanGrantlag_{iz}$ is the average grant lag for all Chinese invention patents that are filed in the past 3 years and weighted over the technology presence of the observed patent. *Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 13: Estimations of Rate of Technical Knowledge Obsolescence and SIPO Invention Patent Administrative Dynamics on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to France.)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{iz} (*weighted IPC*)	8.9954	2.5366	4.333	-19.7390	4.5234	-19.5439
(*averaged over periods t, t-1, t-2*)	(1.0417)***	(5.8798)	(2.0067)**	(7.8511)**	(2.0468)**	(8.0332)**
Mean $Grantlag_{iz}$	-0.0002	-0.0015	-0.0007	-0.0056	-0.0004	-0.0053
(*averaged over periods t, t-1, t-2*)	(0.0003)	(0.0014)	(0.0005)	(0.0016)***	(0.0005)	(0.0016)***
Mean STD_{iz} * *Mean* $Grantlag_{iz}$		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
Cohort * Province 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 probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to France) that are filed in the past 3 years and weighted over the technology presence of the observed patent. $MeanGrantlag_{iz}$ is the average grant lag for all Chinese invention patents that are filed in the past 3 years and weighted over the technology presence of the observed patent. *Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 14: Estimations of Rate of Technical Knowledge Obsolescence and SIPO Invention Patent Administrative Dynamics on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, to Great Britain.)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{iz} (*weighted IPC*)	6.1778	3.3101	5.4877	-4.5520	5.4740	-4.3120
(*averaged over periods t, t-1, t-2*)	(0.7313)***	(3.6939)	(1.3300)***	(6.1908)**	(1.3961)***	(6.2456)
Mean $Grantlag_{iz}$	0.0000	-0.0005	-0.0007	-0.0025	-0.0004	-0.0022
(*averaged over periods t, t-1, t-2*)	(0.0003)	(0.0009)	(0.0004)	(0.0011)**	(0.0004)	(0.0011)**
Mean STD_{iz} * *Mean* $Grantlag_{iz}$		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
Cohort * Province 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 probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to Great Britain) that are filed in the past 3 years and weighted over the technology presence of the observed patent. $MeanGrantlag_{iz}$ is the average grant lag for all Chinese invention patents that are filed in the past 3 years and weighted over the technology presence of the observed patent. *Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).

Table 15: Estimations of Rate of Technical Knowledge Obsolescence and SIPO Invention Patent Administrative Dynamics on Choice of Patent Protection (Chinese invention patent or Chinese utility model) for all EPO patent applications with Chinese Priority. (Dep. Var = Dummy equals to 1 if applied for **utility model**, Mean=0.161 for all EPO patent applications. Rates of technical knowledge obsolescence are calculated using all EPO patents applied during 1998-2005 and designated, but not limited, Germany, France and Great Britain.)

Dependent Variable:	Patenting choice					
	Germany		France		Great Britain	
	All	All	All	All	All	All
	(1)	(2)	(3)	(4)	(5)	(6)
Mean STD_{iz} (*weighted USPC*)	11.7108	9.9585	9.1212	6.0588	6.1827	6.3558
(*averaged over periods t, t-1, t-2*)	(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_{iz} * 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*Province 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 probit models. The sample includes European Patent Office patent applications with Chinese Priority from 2001-2006. Heterogenous robust standard errors, clustered at assignee level, are shown in parentheses. Standard errors are clustered at each patent's primary International Patent Classification (IPC). *: p<0.10; **: p<0.05; ***: p<0.01. The dependent variable is a dummy variable that equals to one if the patent is filed for *utility model* in China. $MeanSTD_{iz}$ is the average percentage of patents that are given up within 4 years from issue date for all EPO patents (designated, but not limited, to Germany, France and Great Britain) that are filed in the past 3 years and weighted over the technology presence of the observed patent. $LargePatentPortfolio$ a dummy that equals to one if the firm's stock of invetion patent, prior to filing the patent under observation, is greater than the average size of patent portfolio in the sample (16 patents). *Grant* is a dummy variable that equals to one if the EPO patent is granted by April, 2011. *Patent Characteristics* include number of inventors, number of assignees at application, number of claims, whether the patent application is a continuation application. *Cohort * Province*: 0/1 indicator variable for application year * province. *Technology Field Dummies*: 0/1 indicator variables for technology fields (total of 604 4-digit IPC fields).