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The Effects of Patent Characteristics as Signals on the Growth of Follow-on Innovations: Evidence from Chinese Patenting Activities in U.S

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THE EFFECTS OF PATENT CHARACTERISTICS AS SIGNALS ON THE GROWTH OF FOLLOW-ON INNOVATIONS: EVIDENCE FROM CHINESE PATENTING ACTIVITIES IN U.S.

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Abstract

As global trade and business activities intensified, cross-national patenting activities have been playing an increasingly important role in the process of innovation accumulation and growth. However, few studies (to my knowledge) have examined the characteristics of cross-national patents and their relationship to the accumulation and growth of innovation, especially in the context of a developing versus a developed country.

Motivated by the anecdotal evidence and 'Patent Signaling Theory' (Spence, 1973), I investigate the possible influential factors on the 'quality' of a US patent with a Chinese priority[1] (thereafter 'US-CN' patent) and their impact on the growth of follow-on innovation. By developing and analyzing a unique dataset of 4490 U.S. and

[1] In patent, a priority right or right of priority is a time-limited right, triggered by the first filing of an application for a patent. The priority right belongs to the applicant or his successor in title and allows him to file a subsequent application in another country for the same invention, design or trademark and benefit, for this subsequent application, from the date of filing of the first application for the examination of certain requirements. 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.

Chinese patent matched pair from both U.S. Patent and Trademark Office (USPTO) and State Intellectual Property Office (SIPO), this study investigates the impact of patent strength, patent scope, cross-national inventors, multinational assignees and strength of intellectual property rights (IPR) regime on the growth of innovation in the U.S. The data set consists of patents that are first filed in China, a developing country with uncertain IPR, and subsequently filed and patented in the U.S., a developed country with a mature economy and strong IPR protection.

I employ the negative binomial regression model and find that the number of patent claims, patent classes, cross-national inventors and of multinational assignees have a significant and positive impact on the forward citations[2] of the focal patents. I also find that developing a patented innovation under a strong IPR regime does not necessarily increase its follow-on use and innovations as proxied by its forward citations. This work has significant management implications for firm strategies and technology competitiveness especially domestic firms and multinational corporations with activities across national boundaries.

[2] A citation is a reference to a published or unpublished source. The backward citations of a patent identify its antecedents (original patent which it builts upon) and the forward citations identify the subsequent patents which builts upon it. Forward citations link the relationship between an original patent and subsequent technological developments which build upon it (i.e. its descendants)

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Acknowledgement

This thesis, to me, is a drive for continuous learning and the completion of it acts like a key to a door, behind which the exciting world of Management is.

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Lastly, I wish to dedicate this thesis and express my love to my parents in China for their care and love on me over so many years.

1. Introduction

Technology plays a key role in determining productivity and economic growth (Easterly and Levine, 2001; Hall and Jones, 1999; Prescott, 1998). As global trade and business activities intensified, cross-national patenting activities have been playing an increasingly important role in the process of accumulation and growth of innovation, gaining attentions from firms and scholars alike.

According to the 'capabilities theory of the firm' (Langlois, 1992), firms are becoming increasingly dependent on their ability to establish a presence at an increasing number of locations to access new knowledge and capabilities (Dunning, 1997; Kuemmerle, 1997). Kuemmerle (1999a) also remarked that the 'capability exploiting motive for foreign direct investment (FDI) in R&D has long been the dominant view, in international business literature, to characterize the nature of expatriate technological activities. However, Most of the past literature focused only on the technology inflow from developed countries to developing countries. For example, Singh (2006) argues that in technologically advanced countries, knowledge outflow to foreign MNCs greatly outweighs knowledge inflows. Lapan and Bardhan (1973) commented that the domestic firms in developing countries might actually have less rather than more to gain in knowledge diffusion from MNCs because their technology might become too advanced to have direct applicability for these firms. However, few scholars have studied the technology flows from a developing country to a more developed country.

Cross-national patenting activities from developing countries to developed countries are growing rapidly nowadays. From 1995 to 2004, the number of U.S. patents obtained by U.S. firms based on technologies developed in non-OECD countries has more than doubled. In 2007, the overseas Chinese patent applications have reached 5401, ranked 7th closely after US, Japan, Germany, France, Korea and UK. The increasing Chinese overseas patenting activities are also gaining importance in the world's technological stage. On April 2008, a Chinese electronic firm, Netacin, announced their success in the litigation of patent infringement against the second biggest mobile storage vendor in the US—PNY. Netacin ended up granting a licensing agreement to PNY, setting the first example of Chinese firm profiting from overseas licensing.

Although Chinese overseas patent applications have increased dramatically and are now playing an important role in the global technology innovation, it is much under-investigated and poorly understood. For a long time, certain attributes of patents have been an important research issue among scholars. Motivated by the model developed by Lanjouw and Schankerman (1999), the value and technological importance ('quality') of a patented innovation can be revealed by a set of four indicators: the number of patent claims, forward citations, backward citations and patent family size. I decided to investigate the possible influential factors on the 'quality' of a US patent with Chinese priority (thereafter 'US-CN' patent) and their impact on the growth of follow-on innovation. By creating a unique dataset through matching 4490 U.S. patents from U.S. Patent and Trademark Office (USPTO) with their corresponding Chinese priorities from State Intellectual Property Office (SIPO), this paper will investigate the impact of certain patent characteristics, namely, patent strength, patent scope, inventor countries and assignee countries on the growth of innovation in the context of cross-national patenting activities, especially when the patent is filed first in a developing country (China) with more uncertain intellectual property rights (IPR), then in a mature and bigger foreign market (The United States).

This paper contributes new insights in the following ways: First, it attempts to fill in the research gap to understand a representative sample of matched domestic and foreign filing of essentially the same patent and examined their overall impact. For example, Allred and Park (2007) investigate the relationship between patent strength and international innovation diffusion. They find that for developing economies, patent strength negatively affects domestic patent filings but does not significantly affects R&D and foreign patent filings. However, they did not examine the relationship between the matched domestic and foreign patent counterpart. Second, by focusing on the Chinese overseas patenting activities in US, this paper will provide new insights of the impact of a developing country’s research capability on the technological innovation of a more developed country.

The remainder of the paper is organized as follows. Section 2 discusses the related theories and literature and proposes a set of empirical predictions. Section 3 describes the data and measures. Empirical design and method is offered in Section 4, while Section 5 presents our empirical results. A final section discusses the results and limitations of the study.

2. Theory and Hypotheses Development

2.1 Growth of innovation

We use the patent citations made by each patent to identify its antecedents (backward citations), and the subsequent patents that cite it to identify its descendents (forward citations). Forward citations link the relationship between an original patent and subsequent technological developments which build upon it (i.e. its descendants) (Trajtenberg, M., Henderson, R., & Jaffe, A. B, 1997).

It is common practice to use data from a single patent granting country like the U.S. (Jaffe and Trajtenberg, 2002) or the U.K. (Lerner, 2002) to standardize the measure of innovation. According to Trajtenberg (1990), Harhoff et al. (1999) and Hall et al. (2005), the number of citations a patent receives serves a good indicator of its importance In addition, patent forward citation is considered one of the most traceable artifacts of knowledge flows (Jaffe et al, 2000), both within and across firms' global R&D networks. Singh (2006) also argues that since existing innovations provide ideas and inspiration for further innovation, patent citations help capture knowledge flows across organizations. Recent studies comparing citation data with direct surveys of inventors show that the correlation between patent citations and actual knowledge flows is high, although it is not perfect (Jaffe and Trajtenberg 2005, Duguet and MacGarvie 2005). So, in this paper, I employ number of forward citations as a measure for the growth of innovation (follow-on research) based on the US-CN patents.

In principle, patents conform well to Spence's original conceptualization of asignal (Spence, 1973): they are costly to obtain and, through the government certification process, provide a mechanism by which the quality of innovative activities can be sorted. The examination process is designed to provide a certification function through the rejection of inventions that fail to meet the standards required for patentability (novel inventions that are useful and not obvious to those skilled in the art). Certain features of a grant patent may reveal the importance and value of this innovation. At the same time, follow-on researcher may also judge the ‘quality’ of a grant patent by these important features, thus certain kind of grant patents tend to be of greater importance for follow-on innovation (i.e. have more forward citations). In this paper, I attempt to examine the impact different ‘signals’ exhibited by a granted patent on further adoption and use by follow-on innovations especially in the context of Chinese innovations. The patents in the dataset are first filed in China and then in U.S., implying that this innovation is originally developed in China—a developing country with weak IPR protection regime. In the following parts of section 2, I will investigate four important characters of a granted US-CN patent and discuss their relationship with its forward citations separately: (i) patent strength, (ii) patent scope, (iii) inventor countries and (iv) assignee countries. By doing so, I hope to understand the characteristics of patents created by developing countries and their impact on further innovation in developed countries.

2.2 Patent Strength

The number of claims captures patent strength. A patent consists of a set of claims that delineate what is protected by the patent. The principal claims define the essential novel features of the inventions in their broadest form and the subordinate claims describe detailed features of the innovation. As such, claims measure the extent of the innovation protected by the patent (Harhoff & Reitzig, 2004; Lanjouw & Schankerman, 2001). The patentee has an incentive to claim as much as possible in the application, but the patent examiner may require that the claims be narrowed before granting. Since the number of claims per patent varies widely, using claims data might help account for the very large heterogeneity in the value of patents.

A patent granted with a greater number of claims will increase in royalties that may pertain to licensors (Gans, Hsu and Stern, 2008). Lanjouw, Parks and Putnam (1998) also find that patent claim is one of the most representative indicators of the ‘quality’ of innovation. According to Allred and Park (2007), for developed economies, patent strength positively affects firm-level research and development (R&D). It indicates that if a US-CN patent is assigned more claims by the patent examiner, it is probably inferred a relatively higher quality compared to other US patents with less claims. Firms and organizations thus may find it more assuring (or simply necessary) to cite patents that are of more claims. I therefore predict:

Hypothesis 1: A granted US-CN patent with more claims leads to more subsequent innovation adoption (captured by its forward citations).

2.3 Patent Scope

Scholars increasingly recognize the scope of patent protection as an important public policy instrument. Green and Scotchmer (1990), Scotchmer (1990), Matutes, Regibeau, and Rockett (1992) have examined the impact of patent scope on the diffusion of innovations and technological collaboration. Austin (1993) examined the three-day net-of-market returns around 52 patent awards. For patents assigned to three or more IPC classes, he finds that the difference between the returns of the awardees and those of the rivals much bigger than narrower patents. Lerner (1994) analyzed the impact of patent scope on citations through a regression analysis. He shows that patents assigned to more four-digit IPC classes are more likely to be cited in subsequent patent documents and to be litigated. In terms of impact of patent scope on subsequent knowledge production, Huang and Murray (2009) find that increasing the scope of patents deters subsequent public knowledge production (in the context of life sciences) and contributes to the anti-commons effect (Heller and Eisenberg, 1998).

Based on Trajtenberg, Henderson and Jaffe (1997) and Lerner (1994), I employ the number of patent classes as a proxy for patent scope. The patent applicant has a legal duty to disclose any knowledge of the original patents it built on (antecedents), but the decision regarding which patents it should cite ultimately rests with the patent examiner. The framework for the examiner's search of previous innovations is the patent classifications system, which consists of over 100, 000 patent subclasses, aggregated into about 400 3-digit patent classes. The combination of citation data, detailed technological classification, and information about each inventor provides a unique mechanism for placing research and research results in their broader technological and economic context (Trajtenberg, Henderson and Jaffe, 1997). Thus, if a US-CN patent is to allow broader classes by the patent examiner, it is probably considered relatively more innovative and higher quality compared to other US patents with less claims. This may also become a patent 'quality' signal for the firms or organizations in related area. Thus, subsequent innovation adoption may increase when a US-CN patent has more patent classes:

Hypothesis 2: A granted US-CN patent with broader patent classes leads to more subsequent innovation adoption (captured by its forward citations).

2.4 Cross-national Inventors

The knowledge-based view argues that firms facilitate interpersonal networks and a social context that enable transmission of tacit knowledge over large distances (Hedlund, 1986; Bartlett and Ghoshal, 1989; Kogut and Zander, 1993; Nohria and Ghoshal, 1997). Reagans and McEvily (2003) also argue that the network range, ties to different knowledge pools, increases a person's ability to convey complex ideas to heterogeneous audiences. Their results indicate that both social cohesion and network range ease knowledge transfer, over and above the effect for the strength of the tie between two people. Thus, collaboration between inventors from different countries probably has an advantage of better knowledge complementation and better "resources allocation".

The detailed information patents provide also helps in identifying the geographic distribution of human capital utilized by U.S. firms, as well as the collaboration among inventors. Reagans and Zuckerman (2001) described how interactions among scientists with non-overlapping networks outside of their team improved productivity. Collaboration among scientists with different external contacts bridged gaps. Bridging structural holes (Burt, 2004) in the external network enabled the scientists to access and share with each other diverse knowledge, resulting in greater creativity and innovation, thereby improving the team's overall productivity. Thus:

Hypothesis 3: A granted US-CN patent with more cross-national inventors leads to more subsequent innovation adoption (captured by its forward citations).

2.5 Multinational Assignees

First, according to ‘capabilities theory of the firm’ (Dunning, 1997; Kuemmerle, 1997), Firms are becoming increasingly dependent on their ability to establish a presence at an increasing number of locations to access new knowledge and capabilities. As a consequence, in an increasing number of cases, firms will invest in R&D abroad not so much to exploit their existing competitive advantages, but to gain new advantages or complementary assets which help sustain or further their global competitive competencies. China and other emerging economies possess a growing pool of human capital potentially valuable for R&D. According to the Boston Consulting Group (2005), China, India, and Russia will likely provide more than two million new scientists and engineers per year by 2010. Moreover, the R&D conducted in these countries often exceeds that required for localization or government-enforced technology transfers. For example, GE Medical Services integrates technologies from its labs in China, Israel, Hungary, France, and India into everything from new X-ray devices to million dollar CT scanners (Engardio, 2003).

Second, Economic growth worldwide is highly dependent on international diffusion of knowledge (Romer, 1990; Grossman and Helpman, 1991). However, knowledge is often tacit and not easy to transmit as blueprints (Polanyi, 1967; Nelson and Winter, 1982). This can cause knowledge diffusion to be geographically localized, an argument supported by numerous empirical studies (Jaffe, 1993; Audretsch and Feldman, 1996; Branstetter, 2001; Keller, 2002). Cross-national research collaboration may help to break this obstacle of geographical knowledge division and thus promotes the growth of technological innovation. On the other hand, Trajtenberg (1997) argue that more original research, as well as research that draws from far removed technological areas, lead to innovations of wider technological applicability. More reliance on scientific resources also enhances the generality of outcomes.

Taking the above two factors into account, we may infer a patent developed by multinational assignees probably have higher ‘quality’. Similarly, as an important patent signal, a granted US-CN patent with multinational assignees will lead to more follow-on innovations to build on it. Therefore:

Hypothesis 4: A granted US-CN patent with more multinational assignees leads to more subsequent innovation adoption (captured by its forward citations).

2.6 Strength of IPR Regime

There is a rich stream of the studies on the strength of external IPR institutions and their impact on innovation. Under the prospect theory (Kitch, 1977), a stronger patent system gives pioneers incentives to commercialize and organize the market better for follow-on innovation (via licensing). Zhao (2006) argues that weak external IPR proection leads to low returns to innovation and underutilization of innovative talents and more internalization of firm R&D activities. In a more recent study, Huang (2009) finds the reduction of uncertainties in IPR conditions, specifically patent enforcement uncertainty and patent market value uncertainty, negatively impacts (by over 20%) the production and accumulation of follow-on knowledge within innovative firms and organizations. In other words, an increase in IPR certainty enhances externalization of firm knowledge activities (through mechanisms such as out-licensing). According to Mansfield (1994), perceptions of strong IP rights abroad had a positive effect on incentives to transfer technologies abroad.

The standard argument for why innovation may be positively stimulated under a strong patent protection in developed countries is that stronger patent rights increase the degree of appropriability of the returns to innovation (Landes and Posner, 2003; Scotchmer, 2004; Allred and Park, 2007). Considering developing countries, we see that innovation is likely to be positively influenced by knowledge disclosures from patents and the appropriability effect of patent protection (Siebeck, 1990). Ordover (1991) argues that protection of intellectual property through strong patent laws is taken as a reflection of broader social concerns for long-run growth and technological progress. Appropriately structured patent law and antitrust rules can together ensure incentives for R&D and also induce cooperation among firms in diffusing R&D results through licensing and other means.

Sherwood (1997) conducted case studies for 18 developing countries and concluded that poor provision of intellectual property rights deters local innovation and risk-taking. In cross-country studies, several works find a positive influence overall of patent protection on trade, FDI, and licensing (Maskus and Penubarti, 1995; Smith, 2001; Yang and Maskus, 2001; Branstetter, 2004; Park and Lippoldt, 2005; Gans, Hsu and Stern, 2008).

Based on the rich literature, we can infer that under a strong IPR regime, patent ‘signaling’ effect will be bigger. Thus, I predict H5:

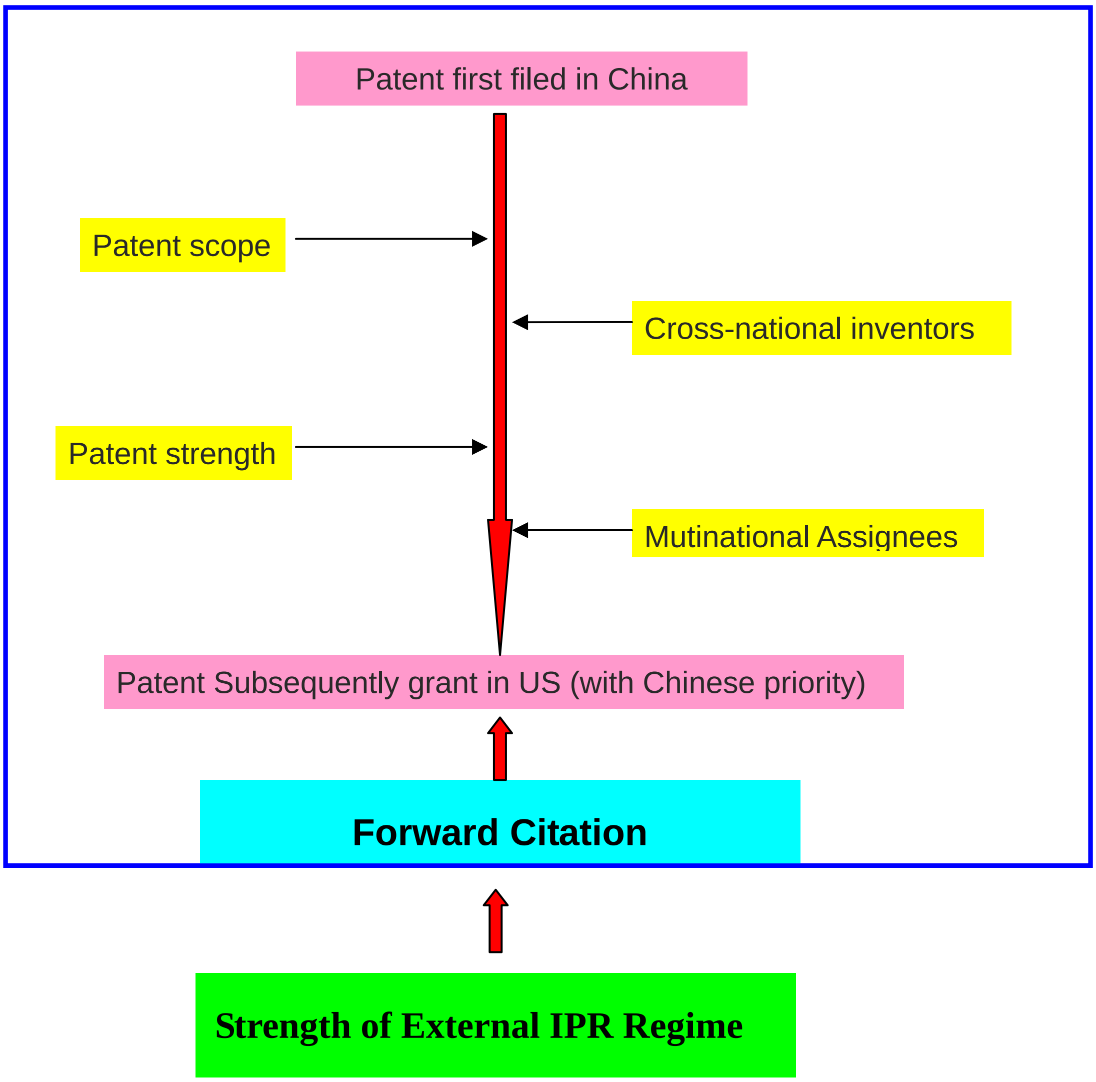
Hypothesis 5a: The signaling effect of the number of patent claims on the forward citations of the granted US-CN patent will be stronger if the focal patent is developed under a strong IPR regime versus a weak one.

Hypothesis 5b: The signaling effect of the number of patent classes on the forward citations of the granted US-CN patent will be stronger if the focal patent is developed under a strong IPR regime versus a weak one.

2.7 An Illustration

The impact of a US-CN patent characteristics as signals on the growth of follow-on innovation is displayed in Figure 1. As illustrated, if a patent is first filed in China and then subsequently grant in US, its characteristics of patent scope, patent strength, cross-national inventors and multinational assignees will have a moderating effect on the forward citation of the patent subsequently grant in US. What is more, this moderating effect will also vary under different strength of external IPR regime.

Figure 1 Relationship of US-CN Patent Characters and Its Impact on Forward Citations



3. Data, Sample and Measures

To test these hypotheses, an empirical strategy is needed to show the above signaling effects of the US-CN patents. I therefore construct a longitudinal dataset based on 4490 patent match pairs from both SIPO and USPTO to analyze its overall impact. Furthermore, for robustness check, I conduct a subsample empirical analysis within 853 patents where at least one of the patent assignees is an IPO firm.

3.1 Sample design and data gathering

One of the contributions `of this paper is its focus on the impact of patented innovation from developing country on the technology development in developed countries. Thus, the US granted patents with Chinese priority are favorable in that 1) The US patent system provides the world most complete and accurate patent data information. 2) The Chinese filing in US is increasing rapidly in recent years and contributes a great part (the 7th biggest) of the world overseas patenting activities.

To obtain the US and Chinese patent match pairs, I first downloaded the entire population of 6236 US grant patents[3] with at least a Chinese priority from Delphion Database. In patent law, a priority is a legally enforceable and officially conferred status after stringent examination that establishes the first novelty (or filing) of a patented invention. The priority right belongs to the applicant or his successor in title and allows him to file a subsequent application in another country for the **same** invention, design or trademark and benefit, for this subsequent application, from the

[3] Inclusive of all data until November 6th, 2008

date of filing of the first application for the examination of certain requirements. 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. As design patents do contain substantial creative and technological research capability (and are therefore not within the scope of this study), I have excluded all 1300 of them leaving only 4936 inventions and utilities model patents which contains real innovative work. The USPTO database contains useful information including Title, National Class, Publication Number, Number of Claims, Assignee Name, Assignee Country, USPTO Assignee Code, Application Number, Application Date, Number of Forward References, Inventor Name, Inventor Country, and Priority Number. Second, according to the 'priority number' in USPTO, I identified an earliest Chinese priority of this US grant focal patent as its origin. Necessary information of this corresponding earliest Chinese priority can be manually matched and checked in the SIPO website using fields such as titles, abstract, application date, inventor names, inventor countries, grant date and grant publication date, etc. After excluding missing and incomplete entries, we ended up with 4543 successful matched pairs. Lastly, we excluded those US focal patents whose application date in US is earlier than the one in China as this study focuses only on patented innovations first filed and developed in China. The final data set contains only 4490 US-CN matched patents.

We got IPO firm's financial data such as assets, R&D and sales from Compustat. Among the 4490 US-CN matched patents, 853 of are IPO firms and have their financial records in Compustat. Thus, combining with these firm's financial data, I conduct the second subsample robustness check.

3.2 Measures and Variables

3.2.1 Dependent Variable

The dependent variable, nFC, is the number of forward citations of the US focal patents. It is a measure of the growth of follow-on innovation

3.2.2 Independent Variable

I construct four independent variables as measures of patent signals, namely, nclaim, nclass, ncountry, and ninvencoun. Nclaim is number of patent claim. It is a measure of patent strength**.** Nclass is the number of national class[4] of the US focal patent. It is a measure of patent scope**.** Ninvencoun is the number of different countries in inventor countries. It is a measure of cross-national inventor. Last, Ncountry is the number of different countries in assignee countries. It is a measure of multinational assignees.

In addition, in order to test H5, I construct 4 interaction effects to examine the effect of patent claims and patent class on forward citations under different patent regime strength [5] , namely, nonUSiprstrongclaim, nonUSiprstrongclass, USiprstrongclaim, USiprstrongclass:

(i) nonUSiprstrongclaim=mainnonUSiprstrong * number of claim

(ii) nonUSiprstrongclass' = mainnonUSiprstrong * number of class

[4] National class is based on USPTO patent classification regime.
[5] For classification of weak and strong IPR regime environment please refer to Mingyuan Zhao (2006).

(iii) USiprstrongclaim’ = mainUSiprstrong * number of claim

(iv) USiprstrongclass’= mainUSiprstrong * number of class

Thereinto, MainnonUSiprstrong stands for if half or more than 50% inventors are from Non-US IPR strong countries. If yes, then it equals to 1. Otherwise equals to 0. MainUSiprstrong is also a dummy variables standing for if half or more than 50% inventors are from US. If yes, then it equals to 1. Otherwise it equals to 0. Using the criteria from previous empirical studies (e.g. Zhao, 2006), if 50% or more of a patent’s inventors are from strong IPR countries, then the patent is considered to have been developed in strong IPR countries. Thus MainnonUSiprstrong and MainUSiprstrong can be viewed as an indicator of the strength of IPR regime under which the US-CN patent is developed.

By conducting interaction variable ‘nonUSiprstrongclaim’ equals to mainnonUSiprstrong * number of claim, I try to examine whether the effect of nclaim is stronger when most inventors of this US focal patent are from non-US IPR strong countries (developed by non-US IPR strong countries). If half or more than 50% inventors are from non-US IPR strongcountries, it equals to nclaim, otherwise it equals to 0. In this way we manage to capture only the nclaim information of a patent at least 50% of whose inventors are from non-US IPR strongcountries. And also we can compare its effect of nclaim on forward citations with those less than 50% of whose inventors are from non-US IPR strongcountries. Similar with interaction variable ‘nonUSiprstrongclaim’, by multiplying ‘mainnonUSiprstrong’ and ‘nclass’, we can measure whether the effect of nclass is stronger when most inventors of this

US focal patent are from non-US IPR strong countries (developed by non-US IPR strong countries). If half or more than 50% inventors are from non-US IPR strongcountries, it equals to nclass, otherwise it equals to 0.

In the same way, by conducting interaction variable 'USiprstrongclaim' equals tomainUSiprstrong *nclaim, I try to examine whether the effect of nclaim is stronger when most inventors of this US focal patent are from US (developed by US). If half or more than 50% inventors are from US, it equals to nclaim, otherwise it equals to 0. Similar with interaction variable 'USiprstrongclass', by multiplying 'mainUSiprstrong' and 'nclass', we can measure whether the effect of nclass is stronger when most inventors of this US focal patent are from US (developed by US). If half or more than 50% inventors are from US, it equals to nclass, otherwise it equals to 0.

3.2.3 Control Variables

"Chemistryindustry" is a dummy variable to control for the industry fixed effect. If the US focal patent belongs to chemistry, then it is coded as 1. Industries vary widely in their propensity to patent and in the usefulness of patents as a measure of innovative activities (Cohen, 2000). Arrow (1962) points out that in chemicals, the industries where patents are most important, one would expect the more R&D-intensive firms to regard patents as much more important than the less R&D-intensive firms because their inventions are more likely than those of the less R&D-intensive firms to be of the type that patents are relatively effective in protecting.

To control the patent assignee effect, I construct variables USPTOAssignee, Ndelphion, assets, R&D, sales and at least1corp. USPTOAssignee is coded as different integers for different assignees. It is used to control for assignee fixed effects because different assignee may have different impact on their patent's forward citations due to their reputation, asset, competition capabilities, etc. Ndelphion is used to control for the organization's research capability. The more patents of an organization got grant in Delphion, the stronger is its research capability. Atleast1corp stands for at least one assignee is a company. As firms and non-firms may have different attitude and behaviors towards patent, it's better to control for this firm fixed effect. Asset, R_d, sales is employed to control for firm size and spending on R&D. Because according to empirical evidence from Germany—company size matters, both for the importance of instruments and the motives to patent (Blind, Edler, Frietsch, and Schmoch, 2006).

As controls of inventor features, I employ variables keycninven and keyusinven. Keycninven is a dummy variable standing for 'half or more than 50% China in inventor countries'. This variable indicates the main entities that create this focal US patent. If it equals to 1, then we know that this US focal patent is mostly innovated by Chinese inventors. It will inherit large part of characters of a Chinese created patent. Otherwise it equals to 0. Keyusinven is a dummy variable defined similarly as Keycninven. If it equals to 1, this US focal patent is mostly innovated by US inventors. Otherwise it equals to 0.

Finally, to control for patent's origin place, I use variables firstpriorCN, firstprior, mainnonUSiprweak, mainnonUSiprstrong, mainUSiprstrong. USFirstpriorCN is a dummy variable measuring the source of the US focal patent. If the first priority of the US focal patent is in China (value equals to 1), then it means that this US patent is first created by China. It is a Chinese invention in nature. Otherwise it equals to 0. FirstpriorUS is similar to FirstpriorCN. If the first priority of the US focal patent is in US (value equals to 1), then it means that this US patent is first created by US. It is a Chinese invention in nature. Otherwise it equals to 0. MainnonUSiprweak is a dummy variable standing for if half or more than 50% inventors are from Non-US IPR weak countries. If yes, then it equals to 1. Otherwise it equals to 0. MainnonUSiprstrong and mainUSiprstrong is of the same definition as previously mentioned. They together control the IPR source and environment of the US focal patent under which it is developed.

3.2.4 Year Dummies

I employ the application date and grant or grant publication date of the matched Chinese priority as a time control. A1 to A23 indicate dummy variables1985-2007, which is application year of the Chinese priority match, while G1 to G23 are dummy variables 1986-2007 or 0. It stands for grantorgrantpub year of the Chinese priority match. It equals to grantpubyear of the Chinese priority (If grantpubyear is missing in SIPO, then it is coded as grantyear of the Chinese priority.). If Gi drops within 1986-2007, it means that the priority of this US focal patent is granted in China in year Gi . If Gi=0, it means that this patent has not been grant yet in China

3.3 Descriptive Statistics of Key Variables

Table 1 to Table 3 below provide the summary statistics of key variables. The mean of ‘nFC’ (number of forward citation) of the focal US patent is 2.54 in the full sample (Table 1) and 2.12 (Table 2) in the sub-sample of only IPO firms. After grouping the full sample by ‘keycninven’(whether half or more than 50% inventors are from China, we can find that nFC of patents with half or more than 50% Chinese inventors (keycninven=1) are smaller than those with fewer Chinese inventores (keycninven=0), both in the full sample in Table 1-1 (2.15 versus 2.82) and in the sub-sample in Table 2-1 (1.90 versus 2.15). However, on the other hand, nclaim and nclass of patents with half or more than 50% Chinese inventors (keycninven=1) are bigger than those with fewer Chinese inventores (keycninven=0), both in the full sample in Table 1-1 (12.57 versus 12.35; 4.06 versus 3.77) and in the sub-sample in Table 2-1 (15.26 versus 13.43; 5.57 versus 3.31).

Table 1 Sample Statistics of Key Variables (Full Sample)

Variable	N	Mean	Std Dev	Minimum	Maximum
nFC	4490	2.542984	7.580418	0	235
Nclaim	4490	12.44744	8.344259	1	91
Chemistryindustry	4490	0.130735	0.337148	0	1
Ncountry	4090	1.093399	0.291026	1	2
Nclass	4490	3.897105	2.876939	1	32
Ninvencoun	4490	1.091982	0.298885	1	3
Ndelphion	3322	2492.09	18703.22	1	610884
Keycninven	4490	0.418486	0.493366	0	1
Keyusinven	4490	0.089087	0.284901	0	1
mainnonUSiprweak	4490	0.729399	0.44432	0	1
mainnonUSiprstrong	4490	0.103341	0.304437	0	1
mainUSiprstrong	4490	0.063252	0.243442	0	1
atleast1corp	4490	0.69265	0.461447	0	1
firstpriorCN	4490	0.850111	0.357002	0	1
firstpriorUS	4490	0.127394	0.333451	0	1

Table 1-1 Summary Statistics Grouped by Keycninven (Full Sample)

	Keycninven=0					keycninven=1				
Variable	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Maximum
nFC	2611	2.820375	7.107299	0	187	1879	2.157531	8.178955	0	235
Nclaim	2611	12.35236	8.737768	1	87	1879	12.57956	7.764775	1	91
chemistryindustry	2611	0.113367	0.317101	0	1	1879	0.15487	0.361877	0	1
Ncountry	2211	1.005427	0.073487	1	2	1879	1.196913	0.397772	1	2
Nclass	2611	3.779012	2.803493	1	28	1879	4.061203	2.968952	1	32
Ninvencoun	2611	1.081578	0.2834	1	3	1879	1.10644	0.31867	1	3
Ndelphion	1883	4010.86	21085.96	1	610884	1439	504.7123	14798.68	1	558409
Keycninven	2611	0	0	0	0	1879	1	0	1	1
Keyusinven	2611	0.1509	0.35802	0	1	1879	0.003193	0.056433	0	1
mainnonUSiprweak	2611	0.534661	0.498893	0	1	1879	1	0	1	1
mainnonUSiprstrong	2611	0.163156	0.369579	0	1	1879	0.020224	0.140802	0	1
mainUSiprstrong	2611	0.104941	0.306536	0	1	1879	0.005322	0.072777	0	1
Atleast1corp	2611	0.738031	0.43979	0	1	1879	0.62959	0.483043	0	1
firstpriorCN	2611	0.749904	0.433151	0	1	1879	0.989356	0.102646	0	1
firstpriorUS	2611	0.214094	0.410271	0	1	1879	0.006919	0.082912	0	1

Table 2 Summary Statistics of Key Variables (Sub-Sample)

Variable	N	Mean	Std Dev	Minimum	Maximum
nFC	864	2.121528	8.537033	0	187
Nclaim	864	13.69329	6.855378	1	63
Chemistryindustry	864	0.09375	0.291649	0	1
Ncountry	863	1.00927	0.095889	1	2
Nclass	864	3.636574	2.886795	1	32
Ninvencoun	864	1.119213	0.331297	1	3
Ndelphion	864	5765.58	22144.8	1	567905
Keycninven	864	0.142361	0.349623	0	1
Keyusinven	864	0.087963	0.283405	0	1
mainnonUSiprweak	864	0.824074	0.380978	0	1
mainnonUSiprstrong	864	0.086806	0.281713	0	1
mainUSiprstrong	864	0.065972	0.248377	0	1
Asset	864	21163714	26749181	0	135000000
R_d	575	906918.2	1633074	0	6015000
Sales	859	31930754	25824643	0	109000000
firstpriorCN	864	0.887732	0.315879	0	1
firstpriorUS	864	0.097222	0.296432	0	1

Table 2-1 Summary Statistic Grouped by Keyciniven (Sub-Sample)

	Keycninven=0					keycninven=1				
Variable	N	Mean	Std Dev	Min	Max	N	Mean	Std Dev	Min	Max
nFC	741	2.157895	9.080312	0	187	123	1.902439	3.920134	0	22
Nclaim	741	13.4332	6.71283	1	63	123	15.26016	7.498456	1	39
Chemistryindustry	741	0.076923	0.266649	0	1	123	0.195122	0.397915	0	1
Ncountry	740	1.001351	0.036761	1	2	123	1.056911	0.232619	1	2
Nclass	741	3.31444	2.42502	1	19	123	5.577236	4.341957	1	32
Ninvencoun	741	1.133603	0.348303	1	3	123	1.03252	0.178103	1	2
Ndelphion	741	6621.47	23763.75	1	567905	123	609.4065	3513.29	1	24893
Keycninven	741	0	0	0	0	123	1	0	1	1
Keyusinven	741	0.102564	0.303594	0	1	123	0	0	0	0
mainnonUSiprweak	741	0.794872	0.404068	0	1	123	1	0	1	1
mainnonUSiprstrong	741	0.101215	0.301816	0	1	123	0	0	0	0
mainUSiprstrong	741	0.076923	0.266649	0	1	123	0	0	0	0
Asset	741	22820331	26391315	0	135000000	123	11183611	26826221	0	1.32E+08
R_d	494	1034938	1720595	0	6015000	81	126158.5	416004.8	0	3644672
Sales	736	35773107	24157731	0	109000000	123	8939109	23501275	0	1.06E+08
firstpriorCN	741	0.871795	0.334544	0	1	123	0.98374	0.126992	0	1
firstpriorUS	741	0.112011	0.315593	0	1	123	0.00813	0.090167	0	1

Table 3 Correlation Matrix of Key Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	nFC	1																		
2	Nclaim	0.0621	1																	
3	Chemistryindustry	0.0374	0.0591	1																
4	Ncountry	-0.0814	0.1139	-0.0741	1															
5	Nclass	0.0892	0.0967	0.2132	0.0042	1														
6	Ninvencoun	-0.027	0.1286	-0.0287	0.3557	0.0141	1													
7	Ndelphion	-0.0095	0.0107	-0.0171	-0.0396	-0.012	0.0041	1												
8	Keycninven	-0.0431	0.0134	0.0607	0.3279	0.0484	0.041	-0.0929	1											
9	Keyusinven	0.0913	0.1959	0.0318	-0.0717	0.0664	0.0973	0.1035	-0.2558	1										
10	mainnonUSiprweak	-0.0418	-0.0655	-0.0151	0.1496	-0.0404	0.0046	-0.1192	0.5167	-0.4994	1									
11	mainnonUSiprstrong	0.0232	0.0006	0.0116	-0.0035	0.0124	0.0302	0.0511	-0.2316	-0.1062	-0.4898	1								
12	mainUSiprstrong	0.1095	0.1568	0.0376	-0.0625	0.0672	0.1374	0.005	-0.2019	0.5708	-0.3195	-0.0672	1							
13	atleast1corp	-0.1176	0.1495	-0.0567	0.1842	-0.0096	0.155	0.0449	-0.1159	0.0863	-0.0363	0.1564	0.0026	1						
14	Asset	-0.0458	-0.0186	-0.0612	0.0754	-0.0108	0.0379	0.4269	-0.152	0.4996	-0.5249	0.1975	-0.0041	.	1					
15	r_d	-0.0276	0.0288	-0.0223	-0.0002	0.0039	0.0314	0.4669	-0.1953	0.6353	-0.6454	0.1935	0.0059	.	0.9657	1				
16	Sales	-0.1599	-0.0403	-0.1451	0.0724	-0.1695	0.072	0.3479	-0.3663	0.303	-0.2427	0.0141	0.0039	.	0.8622	0.8843	1			
17	firstpriorCN	-0.1076	0.0093	-0.05	0.1245	-0.0723	0.0499	-0.0061	0.3309	-0.1534	0.3889	-0.4703	-0.1831	-0.0674	-0.0028	0.0009	0.1908	1		
18	firstpriorUS	0.1086	-0.017	0.046	-0.1125	0.0785	-0.0528	0.0086	-0.3065	0.1666	-0.3717	0.4518	0.2026	0.0649	0.0162	0.006	-0.1784	-0.91	1	
19	USPTOassignee	-0.1225	0.14	-0.0235	0.2207	-0.0119	0.1621	-0.0944	0.1501	-0.0464	0.3208	-0.0098	-0.0746	0.6049	-0.2352	-0.3419	0.037	0.1068	-0.0987	1

From the above summary statistics we can see several interesting phenomenon. In the full sample of 4490 entries, table 1-1, first, when most of its inventors are from China (keycninven=1), judging from the mean value, a US focal patent tends to have more claims (12.57956) and classes (4.061203) compared to those (claims12.35236, class 3.779012) when most of its inventors are not from China (keycninven=0). Similarly, the ncountry and ninvencoun of the former (1.196913 and 1.10644) are more than the latter (1.005427 and 1.081578). However, the forward citations of the former (2.157531) are less than the latter (2.820375). This seems contradictory with our prediction. Second, judging from the mean of Ndelphion, we can see that when most of its inventors come from China, a US focal patent's assignee tend to have much fewer grant patents (504.7123) in delphion compared to those (4010.86) with mainly non-Chinese inventors. This also reveals that our Chinese original innovation just takes up a relatively low proportion in Delphion. Third, judging from table 1, firstpriorCN, we find that most of these US-CN patents have a Chinese priority earlier than any other country's priority. This proves the creativity and research capability of our Chinese inventors. Most of those US-CN patents have a Chinese origin. This further proves the China contribution to the world's growth of technological innovation.

In the subsample of 853 entries with financial data of IPO firms, similar phenomenon is found. In table 2-2, first, when most of its inventors are from China (keycninven=1), judging from the mean value, a US focal patent tends to have more claims (15.26016) and classes (5.577236) compared to those (claims14.4332, class

3.31444) when most of its inventors are not from China (keycninven=0). Similarly, the ncountry of the former (1.056911) are more than the latter (1.001351). However, the forward citations of the former (1.902439) are less than the latter (2.157895). This seems contradictory with our prediction. Second, judging from the mean of Ndelphion, we can see that when most of its inventors come from China, a US focal patent's assignee firm tends to have much fewer grant patents (609.4065) in delphion compared to those (6621.47) with mainly non-Chinese inventors. This also reveals that our Chinese original innovation just takes up a relatively low proportion in Delphion. On the other hand, as IPO firms average grant patents in delphion are relatively more than all organization's average, we can see that IPO firms tend to use the cross-national patenting activities as a strategy more frequently than any other forms of organizations. Third, judging from table 1, firstpriorCN, we also find that most of these US-CN patents have a Chinese priority earlier than any other country's priority. At last, as the average assets (11183611) of the IPO firms when keycninven equals to 1 is much fewer than those (22820331) of keycninven=0, we can infer that the IPO firms behind a Chinese innovation is relatively smaller.

According to the correlation matrix Table 3, most of our key variables are unrelated (with correlation less than 0.5) except for only a few pairs. However, those related variable pairs are reasonable and thus allowable. For example, variable 'asset', 'r_d' and 'sales' are highly correlated. Especially 'asset' and 'r_d' has a correlation as high as 0.9657. However, this correlation is explainable. According to commen sense, if a company has more assets, which means it is relatively bigger than other firms.

Thus, it has the capability and tends to invest more in R&D spending. So these two variables are likely to be correlated. To set another example, 'mainnonUSiprweak' is highly related with variable 'keycninven' with a correlation number 0.5167. This is quite straightforward. If a patent is developed mainly by Chinese inventors, the probability is high that half or more than 50% of its inventors are from Non-US IPR weak country, namely, China.

4. Methods and Empirical Approach

4.1 Regression Model

As the dependent variables—number of forward citations is a positive integer, I employ a Negative Binomial Model for regression (NBRM).

Our dependent variable is number of forward citations. It is total count of all citations of a US focal patent by November 6^{th}, 2008. Using citation data requires us to build our estimations around a count data model. Our approach is to look at the impact of certain 'patent signal' on subsequent innovation adoption (captured by its forward citations). Our citation data is highly right skewed (with skewness of 13.73) and the dependent variable, numbe of forward citations (nFC) exhibits overdispersion where the variance (7.58, see Table 1) is significantly larger than the mean (2.54, see Table 1). Therefore the negative binomial regression model (NBRM) is preferred over the common poisson model to accommodate such underlying probability distribution (Hausman, Hall and Griliches, 1984).

Judging from the regression results, if the coefficient of nclaim, nclass, ncountry, ninvencoun 'nonUSiprstrongclaim', 'nonUSiprstrongclass', and 'USiprstrongclass' are all positive and significant, then hypothesis 1—5 will be supported.

I first conducted a full sample regression with 4490 data entries. Then I did a subsample regression with 853 data entries for the following reasons: 1) Those 853 patents are all filled by IPO firms. We can easily get their firm's financial data such as assets, R&D spending and sales and add them as firm's specific controls. Thus, in spite of the smaller sample size of 853, the regression result may be more accurate and persuadable because it excludes additional ‘noise’ caused by firms’ different attributes. Second, by focusing the same situation in purely IPO firms, it may provide us new knowledge of IPO firm’s insights. Even if the result is the same as that in the full sample, we can treat this subsample regression as a robustness check. It further proves that the impact of US-CN patents’ certain character on the growth of innovation in US is probably consistent regardless of different forms of organizations.

4.2 Regression Table

Table 3 below describes the empirical result of full sample (4490 data entries) regression. Model (1) is the baseline models which include only control variables while Model (2) is the regression included only independent variables. Model (3) indicates the full model after combining all IVs and control variables. Model (4) and (5) is aim to test some interaction effects, namely ‘nonUSiprstrongclaim’, ‘nonUSiprstrongclass’, ‘USiprstrongclaim’ and ‘USiprstrongclass’ .

Table 3 Full Sample Regression

Dependent Variable: Number of Forward Citations	Baseline (1)	Independent Variables (2)	Full (3)=(1)+(2)	Add Patent Claim interaction (4)	Add Patent Class Interaction (5)
Independent Variables					
Nclaim		.0145376***	.0186376***	0.018551***	0.0186711***
Ncountry		-1.531209***	.3133753*	0.308144	0.3050794
Nclass		.0749975***	.0347009***	0.034415***	0.0528426***
Ninvencoun		-.0984641	.41247***	0.427552***	0.4010068***
Interaction Variables					
nonUSiprstrongclaim(4)				0.0134656	
USiprstrongclaim(4)				-0.009718	-
nonUSiprstrongclass(5)					-0.0674476*
USiprstrongclass(5)					-0.064377*
Control Variables					
Chemistryindustry		-.0114388	-.2040508*	-0.19906*	-0.1873072*
USPTOAssignee	-9.58e-08		.0001551	-1.11e-07	-1.17E-07
Ndelphion	-8.30e-06		-9.55e-06	-1E-05*	-9.62E-06
Keycninven	-.6867168***		-.8568543***	-0.86112***	-0.8697776***
Keyusinven	.6432041*		-.1269969	-0.17738	-0.064098
mainnonUSiprweak	.6458043*		.0679365	-0.00811	0.097532

mainnonUSiprstrong	.3519242		-.2429415	-0.48256	0.0466959
mainUSiprstrong	.2207252		.098167	0.255072	0.3526089
Atleast1corp	.0831064		.0264358	0.025795	0.0390372
firstpriorCN	-.3820231		-.2270706	-0.1876	-0.2927618
firstpriorUS	-.199451		-.0442815	0.004897	-0.1123046
Year Dummies					
A1-A23 (included)	Included	Included	Included	Included	Included
G1-G23 (included)	Included	Included	Included	Included	Included
Regression Statistics					
Log-likelihood	-4577.2358	-7657.9528	-4527.5064	-4525.9463	-4522.756
Pseudo R2	0.1316	0.0126	0.1383	0.1386	0.1392
P	0.0000	0.0000	0.0000	0.0000	0.0000
Number of Obsevations	3029	4090	3017	3017	3017

*p<0.05; **p<0.01, ***p<0.001

Table 4 below describes the empirical result of sub-sample (853 data entries) regression. Model (1) is the baseline models which include only control variables while Model (2) is the regression included only independent variables. Model (3) indicates the full model after combining all IVs and control variables. Model (4) is based on Model (3) while adds firm's financial data as assets, R&D and sales. Similar with the full sample regression, Model (5) and (6) is aim to test some interaction effects, namely 'nonUSiprstrongclaim', 'nonUSiprstrongclass', 'USiprstrongclaim', 'USiprstrongclass'.

Table 4 Sub-Sample Regression

Dependent Variable: Number of Forward Citations	Independent Variables （2）	Full (3)=（1）+ (2)	(3) Add firm's financial data=(4)	Add Patent Claim interaction （5）	Add Patent class Interaction （6）
Independent Variables					
Nclaim	.0145376***	0.0147861	0.0126996	0.0006594	0.0129583
Ncountry	-1.531209***	1.270059*	1.665167**	1.641496*	1.635694*
Nclass	.0749975***	0.0629551**	0.071393***	7.65E-02***	6.26E-02**
Ninvencoun	-.0984641	0.4877271**	0.39282*	0.4474824**	0.4034156*
Interaction Variables					
nonUSiprstrongclaim(5)				0.0807492**	
USiprstrongclaim(6)				-0.010766	
nonUSiprstrongclass(6)					0.0181197
USiprstrongclass(6)					0.0805196
Control Variables					
Chemistryindustry	-.0114388	0.545731**	0.594692**	0.5780225**	0.5665204**
USPTOAssignee		-2.66e-07	-4.08e-07	-3.64E-07	-3.56E-07
Ndelphion		-8.56E-06	-0.0000168	-0.0000209	-0.0000171
Keycninven		-9.92E-01***	-1.347236***	-1.265247***	-1.330449***
Keyusinven		(dropped)	-0.5612514	1.353451**	-0.5989769
mainnonUSiprweak		0.4511454	(dropped)	1.799321***	(dropped)

mainnonUSiprstrong		-0.2029056	-0.8426635**	(dropped)	-0.9183705*
mainUSiprstrong		-0.3673073	-0.2460491	-0.2576754	-0.5996845
Atleast1corp		(dropped)	(dropped)	(dropped)	(dropped)
firstpriorCN		-0.0325483	0.1261482	0.064596	0.137508
firstpriorUS		-0.1930161	-0.3484976	-0.2495466	-0.3591301
Asset			2.99E-08**	2.35E-08*	2.92E-08*
R_d			-3.03E-07	-1.76E-07	-2.93E-07
Control Variables					
Sales			-1.36E-08	-1.36E-08	-1.29E-08
Year Dummies					
A1-A23	Included	Included	Included	Included	Included
G1-G23	Included	Included	Included	Included	Included
Regression Statistics					
Log-likelihood	-7657.9528	-1050.1459	-907.86688	-902.35465	-907.15749
Pseudo R2	0.0126	0.1958	0.1687	0.1737	0.1693
P	0.0000	0.0000	0.0000	0.0000	0.0000
Number of Obsevations	863	786	541	541	541

*p<0.05; **p<0.01, ***p<0.001

5. Results

5.1 Full Sample Regression

5.1.1 Independent Variables

In the full sample regression in table 3, Model (3) is the full model. Judging from Model (3), we find that all the coefficients of the four independent variables in H1 to H4, nclaim, nclass, ncountry, ninvencoun are positive and significant, thus H1 to H4 are all supported.

From Table 3 we see that the coefficient of 'nclaim' in full model (3) is 0.0186376>0 and significant (p=.000). Therefore, *a granted US-CN patent with more claims leads to more subsequent innovation adoption (captured by its forward citations)*. Hypothesis 1 is supported.

The coefficient of 'nclass' in full model (3) 0.037009 is also positive and significant with p=0.001. Thus, *a granted US-CN patent with broader patent classes leads to more subsequent innovation adoption (captured by its forward citations).* Hypothesis 2 is supported.

The coefficient of 'ninvencoun' in full model (3) equals to 0.41247, positive and and significant with p=0.000. It proves that *a granted US-CN patent with more cross-national inventors leads to more subsequent innovation adoption (captured by its forward citations).* Hypothesis 3 is supported.

Similarly, the coefficient of 'ncountry' in full model (3) equals to .3133753>0 and significant at p=0.049. So, *a granted US-CN patent with more multinational* *assignees leads to more subsequent innovation adoption (captured by its forward citations).* Hypothesis 4 is supported.

However, the coefficients of “nonUSiprstrongclaim” and “USiprstrongclaim” in model (4) equal to 0.0134656 and -0.009718 but not significant (with p values equal to 0.221 and 0.304 respectively).Thus, *Hypothesis 5a: “The signaling effect of the number of patent claims on the forward citations of the granted US-CN patent will be stronger if the focal patent is developed under a strong IPR regime versus a weak one”* is not supported.

Similarly, the coefficients of “nonUSiprstrongclass” and “USiprstrongclass” in model (5) equal to -0674476 and -0.064377 respectively. Although they are both significant at p=0.024 and p=0.014, they are negative value which is not as positive as predicted in Hypothessis 5(b). Thus, *Hypothesis 5b: ‘The signaling effect of the number of patent classes on the forward citations of the granted US-CN patent will be stronger if the focal patent is developed under a strong IPR regime versus a weak one’* is not supported either.

For hypothesis 5(b), “nonUSiprstrongclass” and “USiprstrongclass” are significant but negatively related to patent forward citations. This may suggest that for patents mainly from IPR strong countries, nclass has a smaller positive effect on its forward citations compared to IPR weak countries. One of the plausible explanations for this result is that: According to the early patent literature (Arrow, 1962; Nordhaus, 1969; Scherer, 1972) and more recent work by Grossman and Lai (2004) point out that the optimal level of patent protection depends on the characteristics of a technology or market. In general, developing economies produce less radical innovations. The smaller the market size and the lower the capacity to innovate, the lower the optimal strength of patent protection should be (Grossman and Lai, 2004). More direct negative effects of stronger patent protection on innovation may arise because developing countries tend to perform adaptive or imitative R&D (Evenson and Westphal, 1997). Stronger patents increase the cost of technological inputs and reduce their supply, thereby limiting the ability of local agents to learn by imitation or learn by doing (Elkan, 1996; Glass, 2004).

5.1.2 Other Findings: Industry Effect

In the full sample regression, variable 'chemistryindustry' is significant but negatively related to US-CN patent's forward citations. This means that, among all kinds of organizations in the full sample, if a patent is classified as "chemical patent", then it tends to have fewer forward citations.

5.2 Sub-Sample Regression as a Robustness Check

5.2.1 Independent Variables

In the Sub-Sample regression in table 3, Model (4) is the complete model. Results from Model (4) suggest that the coefficients of three independent variables nclass, ncountry and ninvencoun are positive and significant. Thus, H2 to H4 are all supported. However the coefficient of nclaim is not significant anymore (with $p=0.186$). Thus, H1 is not supported.

For H5(a) and H5(b), only one of the four interactions is supported. The coefficient of ‘nonUSiprstrongclaim’ is significant and positive. Thus, H5 is partially supported.

5.2.2 Other Findings

5.2.2.1 Industry Effect

In the Sub-sample regression, variable ‘chemistryindustry’ is significant and positively related to US-CN patent’s forward citations. This means that, among the IPO firms in the sub-sample, if a patent is classified as “chemical patent”, then it tends to have fewer forward citations. The difference between full sample regression result and sub-sample regression result may suggest that only within the large IPO firms, being in the chemical industry actually increases follow-on use and built up of innovation which is consistent with previous literature that patenting is critical in only a few industries and chemical industry being one of the key ones.

5.2.2.2 Firm Size Effect

In the sub-sample regression result, we find a significant and positive relationship (2.99E-08) between firm’s assets and its forward citations. This may suggest that larger IPO firms tend to attract more follow-on innovation.

5.3 Summary of Empirical Results

Overall, the full sample empirical result is consistent with the sub-sample empirical result. The sub-sample regression can be viewed as a robustness check of the full sample regression. In general, H1 to H4 is all supported except for H5. However, failing to support H5 may be due to the special context in developing countries. It may be the increasing cost of technological inputs and reduced supply caused by stronger patent protection that limits the ability of local agents to learn by imitation or learn by doing.

Table 5 Summary Table of the Empirical Results

No	Hypothesis	Result in Full Sample	Result in Sub-Sample
H1	Nclaim	supported	Not supported
H2	Nclass	supported	Supported
H3	Ninvencoun	supported	Supported
H4	Ncountry	supported	Supported
H5	nonUSiprstrongclaim	Not supported	Supported
	USiprstrongclaim	Not supported	Not supported
	nonUSiprstrongclass	Not supported	Not supported
	USiprstrongclass	Not supported	Not supported

6. Discussion and Conclusion

Various industry reports and media articles repeatedly emphasize that R&D labs in emerging economies are integral components of MNEs' worldwide R&D endeavors. Some frameworks have been developed to understand multinational R&D in weak IPR countries. However, the technology outflow from developing countries to more developed countries has not been fully studied. Usually a developing country is under a weak IPR regime while developed countries are often under strong IPR regimes. Nowadays, with more developing countries going overseas and seeking for technology learning and innovation protection, issues related to cross-national strategies of developing countries has drawn more and more attention all over the world. What is its impact to our world and what should these developing countries pay more attention to? What problems will both the knowledge inflow and outflow countries face? Is there any difference between developing countries' knowledge outflow (probably under a weak IPR regime) and developed countries' knowledge outflow (probably under a strong IPR regime)? What is the difference and to what extent is this difference?

Many of these pressing questions beg solutions. Using evidence from Chinese patenting activities in US and employing the patent 'signal theory', this paper attempts to investigate certain characteristics of a Chinese patent subsequently filed and granted in U.S. It shed light on the effects of patent signal characteristics on the follow-on technological innovation adoption and growth in U.S. Using the information of all the "US grant patent with a Chinese priority" (i.e. US-CN patent) derived from USPTO, this paper finds that number of patent claim, number of patent class, number of cross-national inventors and number of multinational assignees has a significant and positive relationship with its forward citations by follow-on innovation, while a patent developed under strong patent regime does not necessarily increase its forward citations and technological innovation.

This finding is inspiring to both management practice and policy application. For management practice, as technology outflow from developing countries to developed countries is becoming more and more intensified, technology managers, inventors and venture capitals have been facing more and more related issues, especially for those from developing countries who want to invest or developed their invention overseas in a more developed country. This paper gives them useful information on what kind of patent will probably attract more continuous research, more follow-on innovation and potentially more licensing profit, that is, a patent filed with more claims, more class and more cross-national inventors and also invented by mutinational firms. These factors, as positive signals, will probably help to increase other people's confidence over the quality of this patent. For policy makers and policy applications, this paper also help to shed light on the degree to which they should approve the number of class and number of claim of a specific patent, especially when this patent is first invented in a developing country and then subesequently grant in a developed country. In this way, inventions from developing countries can be better made use of and spread all over the world.

Past literature has explored technology outflow from developed countries to developing countries. However, as developing countries begin to exert their weight on the international stage, practitioners and academics are more concerned about a framework to understand multinational R&D activities in weak IPR countries. This work contributes to our understanding of firm strategies and technology competitiveness especially domestic firms and multinational corporations with activities across national boundaries.

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