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Weakening of IP Enforcement: Post-eBay Patenting and Licensing in US IP-intensive Industries

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Abstract

This study examines the impact of intellectual property (IP) enforcement on firms? incentives to patent and out-license. Following the pro-patent shift in 1982, the US IP system has been regarded as strong in terms of both IP rights and enforcement. However, in 2006, a precedential US Supreme Court decision has altered the strength of IP enforcement. Exploiting this shift in IP enforcement in the US in comparison to the European context which experienced no change in the IP system during that period, it is shown that upon the diminution in IP enforcement, US firms have decreased their patenting and out-licensing activities. Although the number of patent applications has decreased regardless of firm size, the decline in out-licensing activities is more pronounced for small and medium sized firms. Moreover, the reduction in the number of patent applications is at the same level for upstream technology providers and downstream manufacturers, while technology providers have faced a sharper decline in out-licensing activities. Interestingly, European firms ?heavily patenting in the US? before the Supreme Court?s eBay decision are affected similarly. And lastly, the adverse impact of weakened IP strength on out-licensing is mediated by patenting activities. The study contributes new insights to the innovation and market for technology literatures by depicting how much the patent holders are compensated by the current IP system, and discusses possible IP policy implications.

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Key words: IP enforcement, patenting, market for technology, difference-in-difference

INTRODUCTION

'In an effort to make it harder for patent trolls to obtain injunctions yet another bad decision [U.S. *Supreme Court's eBay case ruling] has weakened the patent system for everyone. Yet, patent trolls,* or non-practicing entities if you prefer, like Acacia Technologies, seem unphased. This shooting ourselves in the foot to kill a fly really has to stop. The fly lives and we have a hole in our foot.'

'Happy 5th Anniversary: The Impact of eBay v. MercExchange' (2011)

(Gene Quinn, patent attorney and the founder of IPWatchdog.com)

The aim of the IP system[1] is to create incentives to maximize the social benefits of the creation of new information while minimizing the social costs, including the costs of administering these rights (e.g. Bessen & Raskind, 1991; Maskus, 2000). Initially, patents were granted mainly to individuals for mechanical inventions based on 'flashes of creative genius.' However, during the twentieth century, patents have taken on commercial importance and that era has witnessed an expansion in both volume of patenting (Kortum and Lerner, 1999) and patentable subject matter.

The impact of IP system on firms' innovativeness is a highly debated topic in the innovation literature. The proponents of a strong IP system contend that it encourages innovation, facilitates market for technology, and enhances vertical specialization and small firm entry (e.g. Arora, Fosfuri & Gambardella, 2001; Arora & Ceccagnoli, 2006; Breschi, Malerba & Orsenigo, 2000; Gans and Stern, 2003; Hall & Ziedonis, 2001). It is argued that a strong IP system facilitates firms' incentives to innovate and engage in IP trade (Arora et. al., 2001; Gans & Stern, 2000; Gans, et.al, 2002). Conversely, the opponents of the strong IP system assert that it stifles innovation through,

[1] This research, with regards to the use of term 'IP system', mainly refers to the 'patent system'. These terms are used interchangibly throughout the paper. Trademark and copyright polices are beyond the scope of this study.

e.g. restricted access to upstream discoveries especially in industries where technologies advance cumulatively (Merges & Nelson, 1990; Scotchmer, 1991), potential hold-up and royalty stacking problems which may emerge when the IP rights are highly fragmented (Cockburn, MacGarvie & Muller, 2010; Galasso & Schankerman, 2010; Heller & Eisenberg, 1998; Lemley & Shapiro, 2006), increased cost of innovation due to escalating defensive patenting and patent portfolio races among firms (Hall & Ziedonis, 2001, Shapiro, 2000), and inflation in patent thickets (Graevenitz, et.al., 2013), patent litigations (Bessen & Meuer, 2005; Galasso & Schankerman, 2010) and trolling activities (Bessen, et.al., 2011; Fischer & Henkel, 2012; Reitzig, et.al., 2007).

The strength of IP system is also at the center of IP policy reform debate. In 2003, US Federal Trade Commission (FTC) reported that the IP system requires an alignment with the antitrust enforcement which can be achieved with a proper balance between patent exclusivity and competition policy. Besides, it is noted that damages awards that under- or over-compensate patent holders in infringement cases may have detrimental effects on innovation and competition. While under-compensation may undermine patent system's incentives to innovate, over-compensation may deter innovation by raising hold-up problems and the risk of investment due to higher switching costs. Protecting the patent exclusivity to incentivize innovation while preventing patent hold-up problem which may undermine innovation and harm consumers is one of the major challenges of IP policy makers.

Is the current level of IP strength in US under- or over-compensating the patent holders? Does a decrease in the IP strength encourage or deter innovation? Does weakening of IP strength enhance or impede market for technology? This research tries to answer these questions by exploiting a momentous Supreme Court decision in 2006, which has shifted the strength of IP enforcement in

the US context. Studying the impact of IP enforcement on patenting and out-licensing activities is important from at least two perspectives. First, the impact of IP rights on firms' incentives to innovate is an unresolved dispute in the innovation literature. Despite more than 40 years of research there is no general consensus on the impact of IP strength and firm innovativeness. This paper is an endeavor to shed more light on our understanding of the relationship between IP strength and firms' incentives to patent and engage in IP trade. Second, if the Supreme Court's decision has shifted the US IP system's balance towards either under- or over-compensating the patent holders, it raises serious issues for IP policy. The debate on the effect of this court decision has thus far been largely theoretical or based on follow-on plaintiff success rates in patent disputes. Little is known about the impact of the Supreme Court's decision on subsequent patenting and out-licensing activities of firms. This research also informs policy makers by presenting how the US IP system has altered upon a shift in the strength of IP enforcement.

The analyses are based on the US Supreme Court's decision on eBay v. MercExchange patent dispute case (2006), which marked a turning point in injunctive relief policy. The US Supreme Court upheld the notion that 'an injunction should not be automatically issued based on a finding *of patent infringement'*. In effect, this ruling has reduced the probability of securing a permanent injunction for infringed patents. Thus, the patent policy debate has entered a new phase with the Supreme Court's decision on eBay case. Exploiting this exogenous shock to the US IP system, patenting and out-licensing activities of US firms in IP-intensive industries are tested with a difference-in-difference estimation, comparing pre- (2001-2005) and post-eBay case periods (2007-2010), with a control group of European firms (i.e. German and Swiss) which experienced no policy change in IP enforcement during that period. The results show that in the post-eBay period, US firms have decreased their patenting and out-licensing activities compared to European firms. However, although the number of patent applications has decreased regardless of firm size, the

decline in out-licensing activities is more pronounced for small and medium sized firms. Moreover, US firms' patent applications and out-licensing activities have diminished in all IP-intensive industries, except medical devices industry which, despite a decline in patenting, shows no significant decrease in out-licensing activities. In addition, the reduction in patent applications is at the same level for upstream technology providers and downstream manufacturers, while technology providers have encountered a sharper decline in out-licensing activities. Besides, European firms 'heavily patenting in US' before the Supreme Court's decision are impacted similar to the US firms. Finally, the adverse impact of weakened IP strength on out-licensing is mediated by patenting activities.

The paper is organized as follows. Next section puts forward the theoretical background on IP system and its effect on innovation and market for technology. The following section propounds the characteristics of US patent policy up until 2006 and how it has changed since then with the Supreme Court's decision on eBay case. It is followed by presentation of the trends in the aggregate data and the empirical results of the firm/year observations. Final section discusses the implications of the results and concludes with explaining the limitations of the current study and identifies further research venues.

THE ROLE OF IP SYSTEM

The role of IP system on firms' incentives to innovate has long been a scholarly interest (e.g. Arrow, 1962; Hall & Ziedonis, 2001; Kaufer, 1989; Kitch, 1977; Kortum & Lerner 1999; Machlup, 1958; Mansfield, 1986; Nelson, 1959; Nordhaus, 1969; Scherer, 1980). As Teece (1986) defines, the IP system refers to the environmental factors that govern an innovator's ability to capture the profits generated by an innovation such as the efficacy of legal mechanisms of protection. In

environments where the IP system is "tight", in other words, the efficacy of legal mechanisms of protection is high, an invention is relatively easy to protect; whereas in "weak" IP systems it is difficult to protect an invention from imitation (Teece, 1986). In their review of the theories on benefits and costs of patents, Mazzoleni & Nelson (1998) propose four broad theories about the purposes of IP system: (a) invention motivation theory, (b) induce commercialization theory, (c) information disclosure theory, and (d) exploration control theory[2]. First, according to the invention motivation theory, patents are needed to provide firms with the requisite incentive to invent, and that this does justify the costs of the temporary monopoly their granting gives. This theory depends on two basic assumptions (Andersen, 2004). One assumption is that not enough inventions will be undertaken without effective incentives; neither invention nor exploitation of inventions will take place unless inventors and capitalists believe they will yield profits, which make it worth their efforts and their financial risks. The other assumption is that IP rights are the cheapest and most effective way for society to hold out these incentives. Second, the induce commercialization theory is based on the fact that many patents are granted at an early stage of the innovation process and a lot of follow-on work is needed before commercialization. Giving the patentees a temporary monopoly provides enough time to commercialize the patented invention and recoup their investment in R&D. Third, information disclosure theory asserts that patents induce disclosure of inventions which may remain as secret otherwise. In that sense, patents are considered to be the society's award to individuals who disclose their inventions. Fourth, exploration control theory suggests that patents enable orderly development of broad prospects. Under this theory, an initial discovery or invention is seen as opening the door for a wide range of follow-on developments or inventions (Kitch, 1977). Issuing a broad patent on a prospect opening invention enables the development of a wide range of possibilities to proceed in an orderly fashion (Mazzoleni & Nelson, 1998). These theories underlie the rationale of the US IP system which grants the patentee the right

[2] For a detailed typology on the rationales for IPRs, See Andersen (2004) 'If 'intellectual property rights' is the answer, what is the question? Revisiting the patent controversies', Economics of Innovation and New Technology, 13:5, 417-442.

to exclude others from making, using, selling the patented subject matter for a fixed period of time in exchange of disclosing a novel, useful, and nonobvious invention (35 U.S. Code § 154).

However, the extent literature on the relationship between the strength of IP system and firms' incentives to innovate present conflicting views. On the one hand, a significant amount of research has highlighted the benefits of a strong IP system (Arora et al., 2001; Kitch, 1977). This body of literature suggests that a strong IP system may facilitate firms' incentives to innovate and engage in IP trade in the market for technology, encourage further investment in R&D with commercial potential, and mitigate disincentives to disclose and exchange knowledge which might otherwise remain secret (Arora et. al., 2001; Gans & Stern, 2000; Hall & Ziedonis, 2001; Merges & Nelson, 1990, 1994). For instance, Kitch (1977) argues that strong patents were valuable precisely because they can function as broad technological prospects. Firms can, thereby, explore and develop new ideas free from the interference of others. Inventive activities can be coordinated in an orderly, efficient manner. Some survey evidence also suggests that, in the US, strong IP system stimulates innovation (Mansfield, 1986). It is also suggested that, within the context of university research, a strong IP system offers important incentives to move nascent discoveries out of the 'ivory tower' and into commercial practice (Hellman, 2007).

Empirical studies of why firms apply for patents also demonstrate that firms do so for many reasons beyond directly profiting from innovation through commercialization and licensing: i.e. to block or 'enclose' rivals (preventing them from pursuing a given line of patented research), signal plans to enter a new technological area or market, facilitate cross-licensing, indicate stock market value, or for defensive reasons, to secure freedom to operate and prevent law suits. (e.g. Cohen et. al., 2000; Hall & Ziedonis, 2001; Harabi, 1994; Kingston, 2001; Levin et al., 1987; Rivette and Kline, 2000a,b). In their seminal work, Cohen, et. al. (2000) also argue that firms' motives to

patent vary by industry. In other words, they assert that firms' motives to patent in discrete product industries, such as chemicals, differ from complex product industries, such as telecommunications and semiconductors. While in the chemical industry firms patent more commonly to block competitors from patenting related inventions, firms engaging in production of more complex technologies patent for using in trade negotiations. Hence, a strong IP system is also believed to encourage strategic patenting of the firms (Hall & Ziedonis, 2001).

On the other hand, opponents of a strong IP system assert that it stifles innovation. For instance, it is argued that the expansion of IP rights results in privatizing the scientific commons and limited scientific progress (Argyres & Liebskind, 1998; Heller & Eisenberg, 1998; Merges & Nelson, 1990; Scotchmer, 1991). In particular, it is asserted that a strong IP system may inhibit the free flow and diffusion of scientific knowledge and the ability of researchers to build cumulatively on each other's discoveries (David, 2000, 2003; Etzkowitz, 1998; Heller and Eisenberg, 1998; Krimsky, 2003; Lessig, 2002). Another body of literature warns for accelerated hold-up and royalty stacking problems specifically in information technology industry where IP ownership is highly fragmented and one patent covers a component or feature of a complex product (Cockburn, MacGarvie & Muller, 2010; Lemley & Shapiro, 2006; 2007). Heller & Eisenberg (1998) argue that license fees negotiated with a number of patentees might stack to the point of overwhelming the value of the final product. Furthermore, strengthening of the IP system is considered as increasing the cost of innovation due to accelerated defensive patenting and patent portfolio races among firms, especially in semiconductors industry (Hall & Ziedonis, 2001, Shapiro, 2000), and the need for navigating through patent thickets (Cockburn, MacGarvie & Muller, 2010; von Graevenitz, et.al., 2013). In a survey of software patents in the US, Bessen & Hunt (2003) have found that most of the software patents, instead of providing an incentive to R&D, function as substitutes for R&D, and are associated with considerably lower levels of R&D intensity. Thus, the impact of IP system

on firms' incentives to innovate still remains as an open debate. In order to test this relationship to provide further empirical evidence on the debate, I propose two competing hypotheses *'innovation* stimulation*'* and 'innovation deterrence' on the relationship between the strength of patent system and firms' incentives to patent.

Hypothesis 1a: The strength of the patent system is positively associated *to the firms'* incentives to patent.

Hypothesis 1b: The strength of the patent system is negatively associated *to the firms'* incentives to patent.

Market for technology literature highlights the role of institutional factors in facilitating IP trade. This body of literature contends that the strength of IP system is an essential factor in firms' licensing activities (Arora & Gambardella, 2010; Conti, Gambardella & Novelli, 2013). From the potential licensor's perspective, one concern is the risk of expropriation. When an invention is disclosed to potential licensees so that they can assess its value, the underlying knowledge may leak out (Arrow, 1962). Arora and Fosfuri (2003) discuss that the potential licensor's incentives to out-license are diminished when the IP system is weak and the firm cannot rely on legal rights to protect the use of the technology. Yet, from the potential licensee's perspective, the scope of the invention may be uncertain and there may be concerns about the possibility of using the invention without infringing it (Gans, et.al, 2002). For instance, Gans, et.al. (2008) show that licensing activities largely take place within a narrow window around the grant of the patent which is argued to reflect the patent system's influence in reducing the uncertainty and asymmetric information regarding the scope of the invention. Thus, market for technology literature underlines the importance of IP system in preventing knowledge expropriation and reducing the uncertainty

regarding the scope of an invention (Arora & Ceccagnoli, 2006; Gans, et.al, 2002; Gans and Stern, 2010). Firms' technology commercialization strategies heavily depend on the level of excludability from imitation (Gans & Stern, 2003). For instance, Gans, et.al. (2002) indicate that in the biotech industry, firms are more likely to out-license their technology when IP system is strong; otherwise, firms are more inclined to commercialize their technology through downstream integration. Moreover, Arora & Ceccagnoli (2006) argue and empirically show that the impact of the strength of IP system on firms' out-licensing activities are stronger when the firm' do not engage in downstream manufacturing. Arora and Gambardella (2010) note that when upstream R&D and downstream manufacturing processes are complementary, an increase in patent protection may have no effect on firms' licensing activities; whereas, a strong patent system increases propensity to out-license when there exists no complementarity between upstream R&D and downstream manufacturing. They also argue that the licensing propensity of small firms, as opposed to large firms, can be more responsive to the patent system's effectiveness. It is also emphasized that the effectiveness of IP system may vary in different industries. The market is argued to function more efficiently in discrete technology industries, such as chemical and pharmaceutical industries, where the patent system is more effective to protect IP (Anand & Khanna, 2000; Cohen, et.al., 2000). Taken together, in a strong IP system, it is expected that the market for technology will operate more efficiently and there will be a high volume of licensing activities.

Hypothesis 2: The strength of the patent system is positively associated *to the firms'* incentives to out-license.

US PATENT POLICY

Pre-eBay Case Period

Starting from early 1980s, important changes in the US IP rights created a pro-patent shift towards a stronger IP regime. Establishment of the Court of Appeals for the Federal Circuit (CAFC) in 1982 to uniform judicial treatment in patent cases was an important step in strengthening the patent protection. CAFC not only consolidated all appeals in patent cases but also appeared as a pro-patent court in handling patent litigations (Cohen, 2005; Hall and Ziedonis, 2001). According to Cohen (2005), the pro-patent shift in US revealed itself mainly in three ways: increase in the plaintiff success rates, expansion in patentable subject matter and extension of eligibility regarding who can patent. For instance, before 1980, 62% of the time a patent was upheld by a district court as valid and infringed, the rate rose up to 90% percent between 1982 and 1990 (Jaffe, 2000). Likewise, plaintiff success rates increased from 61% to 75% after the establishment of CAFC (Lanjouw & Lerner, 1998). The same period also witnessed an expansion in the patentable subject matter. Initially, patentability was extended to life forms with Supreme Court's ruling in Diamond v. Chakrabarty case (1980). This has been followed by Supreme Court's affirmation of patentability of software (Diamond v. Diehr case, 1981) and business methods (State Street Bank and Trust v. Signature Financial Group case, 1998). In addition, a series of legislative changes (i.e. Bayh-Dole Act, Stevenson-Wydler Act) in 1980, permitted universities and government research institutions receiving federal research funds to obtain patent rights over their inventions.

The pro-patent movement in the US has altered the patenting behavior of firms and universities. The annual rate of patent grants increased substantially after 1980 (Hall & Ziedonis, 2001; Kortum & Lerner, 1999). Patenting by both US and foreign firms in US jumped from 61,819 in 1980 to 169,039 in 2003 (USPTO statistics). This was also reflected in the number of patents per million

dollars of R&D, which increased from 0.35 to 0.50 patents per million dollars (Jaffe, 2000). Nevertheless, the increase in patenting has not been uniformly distributed among US industries. Hicks, et. al. (2001) evidenced that patenting has mostly increased in health and information technology fields.

The increase in patenting have brought along with it a notable increase in patent litigations. The number of patent suits filed has doubled over the decade of the 1990s (Clermont & Eisenberg, 2000). The patent trial rate has also doubled the average of federal civil litigation, patent trials have become especially expensive, and filings have increased rapidly (Bessen & Meuer, 2005). Some attributed this increase in the number of patent litigations to the emergence of new actors in the IP market, such as non-practicing entities (NPEs). These entities, due to their business model, do not engage in the production of the technology underlying their patents, but instead make money from royalty payments they obtain directly from their licensees or indirectly in terms of damage awards (Reitzig, Henkel & Heath, 2007).

The raised concerns about pro-patent shift, i.e. anticommons, patent hold-up, royalty stacking etc., and escalated number of patent litigations, in turn, drew attention of US policy makers. In 2003, US Federal Trade Commission (FTC) reported that the patent system requires an alignment with the antitrust enforcement which can be achieved with a proper balance between patent exclusivity and competition policy. It is admitted that the ability of patentees to assert their patents against infringers is important to the patent system's role in promoting innovation and facilitating technology transfer. For this purpose, permanent injunctions are put in place to deter infringement and protect the exclusivity. Three characteristics of injunctions are argued to support innovation: (a) its ability to preserve exclusivity that provides the foundation of the patent system's incentives

to innovate, (b) credible threat of an injunction deters infringement in the first place, (c) a predictable injunction threat will promote ex ante licensing by the parties. However, an injunction can also cause patent hold-up due to high switching costs which may deter innovation. The challenge of protecting the patent exclusivity to incentivize innovation while preventing potential patent hold-up problem which may undermine innovation and harm consumers, led the US Supreme Court in 2006 to unanimously reject a general rule supporting the grant of a permanent injunction following a finding of patent infringement.

eBay Case and Post-eBay Period

In addressing a patent dispute between eBay and MercExchange, a small Virginia based patent holding company, regarding the infringement of one of MercExchange's patents related to the fixed-price auction feature that makes up an integral part of eBay's "Buy It Now" section of its website, the US Supreme Court upheld the notion that 'an injunction should not be automatically issued based on a finding of patent infringement'. The Supreme Court ruled that the traditional "principles of equity" should be applied to permanent injunction decisions for disputes arising under the Patent Act. In other words, the court determined that in order to receive a permanent injunction in a patent litigation the victorious plaintiff needs to demonstrate that: (a) it has suffered an irreparable injury; (b) remedies available at law, such as monetary damages, are inadequate to compensate for that injury; (c) considering the balance of hardships between the plaintiff and defendant, a remedy in equity is warranted; and (d) the public interest would not be disserved by a permanent injunction. In effect, this ruling has reduced the probability of securing a permanent injunction for infringed patents. By removal of the presumption of irreparable injury from equitable balancing, it has become harder especially for small firms, and firms which solely focus on monetizing their patents through licensing and litigation, to obtain an injunction.

While prior to Supreme Court's decision on eBay v. MercExchange case it was unheard of a district court to deny a victorious plaintiff a permanent injunction upon a finding of infringement, after this decision, the denial rates have started to increase. According to Patstats.org, a patent statistics project by University of Houston Law Center, since eBay case (until April 2011), in 43 cases out of 174 a permanent injunction has been denied.

The changed landscape for patent enforcement with its potential impact on innovation has become a highly contested topic in IP policy research. Some argues that issuing permanent injunctions in cases where the plaintiff and the defendant are direct competitors and denying otherwise, can decrease incentives to innovate by small firms, individual inventors and patent licensing firms (Diessel, 2007; Beckerman-Rodau, 2008). The Supreme Court's decision is considered to favor mainly large firms (Diessel, 2007; Tang, 2006). It is argued that this ruling reduces the large firms' incentives to engage in ex ante licensing agreements (Tang, 2006). Thus, the legitimate non-practicing patent holders; i.e. patent pioneers, universities, think tanks, independent inventors, are argued to become easy targets for willful patent infringement (Davis, 2008; Grab 2006). In addition, some scholars question the rationale behind the weakening of patent enforcement, stating that there is lack of evidence that the so-called patent hold-up and royalty stacking problems are pervasive, not sporadic (Denicolo, et.al.,2008). Studying the implications of eBay case decision, Denicolo, et.al. (2008) assert that there is lack of evidence that those alleged problems have had any significant impact on ex ante R&D investments and innovation. They also put forward that, after the Supreme Court's decision on eBay case, patent holders are more likely to be under- than over-compensated, and limiting the patent holder's ability to stop infringing activity will severely diminish the value of the patents.

The Supreme Court's decision on eBay case was followed by other court rulings and legislative changes which have decreased potential damages awards by limiting the royalty base to value of the sub-component reading on the infringed patent (Lucent v. Gateway case, 2009; Laser Dynamics v. Quanta case, 2012), lowered the bar for invalidating patents on the base of obviousness (KSR v. Teleflex case, 2007), raised the bar for evidencing willful infringement (Convolve v. Seagate case, 2007), and introduced inter partes review for invalidating patent claims (America Invents Act, 2011). These subsequent court decisions have added to weakening of patent enforcement and raised further the bar for succeeding in patent assertion (Ludlow, 2014).

A Glimpse at the Aggregate Data

In order to see the impact of the US Supreme Court's eBay case decision on firms' incentives to patent and out-license, an across country trend analysis is warranted. According to the 'innovation stimulation' hypothesis, the downward shift in the strength of patent enforcement upon the Supreme Court's eBay case decision should have decreased the US firms' incentives to patent and out-license compared to European firms. In contrast, the *'innovation deterrence'* hypothesis suggests that the Supreme Court's eBay case decision should have resolved the patent hold-up and royalty stacking problems, which, in turn, facilitates US firms' patenting and out-licensing in the post-eBay period. In addition, from an IP policy perspective, if the US IP system was over-compensating the patent holders which, in turn, was stifling innovation, the corrective action taken by the Supreme Court should have spurred patenting and out-licensing activities in the port-eBay period. Conversely, if the US IP system was optimally- or under-compensating the patent holders, the weakening of IP enforcement should have reduced US firms' incentives to patent and out-license. Figure 1 depicts these IP policy arguments.

Figure-1 about here

It is fruitful to begin the analyses by looking at the aggregate data. Figure-2 shows the first evidence from patenting applications across countries. It presents the aggregate number of worldwide patent applications by US and European (German and Swiss) firms in six IP-intensive industries, in pre- and post-eBay case periods[3]. The figure shows that in the post-eBay case period the US firms decreased their total number of patent applications, while the volume of patent applications by German and Swiss firms remain steady. Out-licensing activities by US firms presents a similar pattern. Figure-3 compares the aggregate volume of out-licensing agreements by US, German and Swiss firms[4]. The figure shows that in the post-eBay case period out-licensing activities of US firms have dropped; whereas, the volume of out-licensing activities by German and Swiss firms remain the same. The aggregate data on worldwide patent applications and out-licensing activities presents the preliminary evidence that upon the diminution in patent enforcement, US firms have decreased their patenting and out-licensing activities compared to European firms which experienced no change in IP policy legislation during that period. The aggregate data supports the *'innovation* stimulation' hypothesis over the *'innovation deterrence'* hypothesis, and shows a rather under-compensation than an over-compensation of patent holders in the post-eBay period.

[3] The data sources are Bureau van Dijk's ORBIS database for US firms and AMADEUS database for German and Swiss firms. These databases provide firm-patent matching information obtained from the PATSTAT database. The patenting information was available for a total number of 161,822 firms in six IP-intensive industries; i.e. chemicals (NAICS 325), machinery (NAICS 333), computer/electronics (NAICS 334), electrical equipment (NAICS 335), medical devices (NAICS 3391), and software (NAICS 5415).

[4] The data sources for out-licensing activities are ktMINE database for US firms and FACTIVA database for German and Swiss firms. These databases categorize licensing agreements depending on the motivation of the parties. The sample is composed of all agreements under the technology transfer category.

Figure-2 about here

Figure-3 about here

Next, if the Supreme Court's eBay case decision has rendered the US less attractive as a destination country of patenting due to weakened patent enforcement, it should have reflected as a reduction in both domestic patent applications of US firms and European firms' patent applications in the US. For this purpose, first a decomposition of US firms' patent applications is provided (Figure-4). The figure shows a decline in both 'domestic' and 'rest of the world' patent applications of the US firms in the post-eBay period. This analysis suggests that the reduction in patenting is an overall decrease in all patenting activities of US firms. Second, in order to check the foreign firm applications for US patents, a decomposition of European firms' patent applications is provided in Figure-5. It is seen that in the post-eBay period, German and Swiss firms have decreased the volume of their patent applications in US, while the total number of patent applications by these European firms remains fairly constant. This further analysis points to the US context's decreased potency as a destination country of patenting in the post-eBay period. These results are in line with the earlier evidence in support of *'innovation* stimulation*'* hypothesis and under-compensation of US patentees.

Figure-4 about here

Figure-5 about here

EMPIRICAL EVIDENCE

Data and Sample

The hypotheses of this study are tested by comparing the volume of patent filings and out-licensing activities in pre- (2001-2005) and post-eBay case period (2007-2010) by US firms with those in a patent system which experienced no legislative change in the strength of IP enforcement in the same period (i.e. Germany and Switzerland). The selection of firms in two European countries as a control group follow the rationale that there exists a sizeable market for technology in these countries and there exists no legal change in their IP systems in the identified period. For the purposes of this study, an initial sample of 495,716 firms (i.e. full population) in six IP-intensive industries, i.e. chemicals (NAICS 325) , machinery (NAICS 333), computer/electronics (NAICS 334), electrical equipment (NAICS 335), medical devices (NAICS 3391) and software (NAICS 5415); in the US, Germany and Switzerland are gathered. The initial sample of US firms are obtained from Bureau van Dijk's ORBIS database while the data on German and Swiss firms is gathered from Bureau van Dijk's AMADEUS database for the period 2001-2010 in the specified IP-intensive industries. One advantage of these databases is that they provide a matching of firms with their patenting information obtained from the PATSTAT database. The firm-patent matching information was available for 161,822 firms which, in turn, provided a panel dataset of 1,455,336 firm/year observations. This dataset is complemented by the licensing activities of the firms. Licensing agreements of US firms are gathered from ktMINE database. It provides the most comprehensive database on licensing agreements for 15,282 deals in US (Fosfuri, Helmers & Roux, 2014). Licensing agreements of German and Swiss firms are obtained from FACTIVA

database. A total number of 1,492 licensing agreements is identified for German and Swiss firms between 2001-2010.

Measures

Dependent variables

Firm Patenting Activities: This construct is measured by the number of patent filings per year by each firm for the period of 2001-2010. Data for the date of patent filings is gathered from ORBIS and AMADEUS databases for US, and German and Swiss firms, respectively. Sampling for firm patenting activities is terminated by the end of year 2010 for the following reason. In September 16th, 2011, America Invents Act came into effect which brought several changes in the US patent system, including inter partes review for invalidating patent claims. Therefore, I test the patenting behavior of firms during 2001-2010, where there is no change in the legal IP rights but rather a shift in IP enforcement following the Supreme Court's eBay case decision.

Firm Licensing Activities: This construct is measured by the number of out-licensing activities per year by each firm in the sample for the period of 2001-2010. Licensing agreements of US firms are gathered from ktMINE database; whereas, licensing agreements of German and Swiss firms are obtained from FACTIVA database. In both databases, licensing agreements are categorized depending on the type of the deal. The sample consists of all the technology transfer agreements available in the databases for US, German and Swiss firms.

Control variables

Operating Revenue: It is measured by the yearly revenue amount (in thousand $) reported by each firm in the sample. Data on operating revenues has been gathered from ORBIS and AMADEUS databases.

Profit Margin: This construct is measured by the yearly percentage of [(profit before tax/operating revenue)*100] reported by each firm in the sample. Data on profit margin has been gathered from ORBIS and AMADEUS databases.

Firm Age: This variable is constructed as such: for each firm in the sample the year of incorporation is gathered from ORBIS and AMADEUS databases. Then, the difference of each year observed from the year of incorporation is taken as the age variable of the firms.

Country: It is measured by creating a dummy variable for each country, i.e. US, Germany and Switzerland, taking the value of 1 if a firm operates in the respective country, 0 otherwise.

Size: Firm size is measured by the categorization provided by ORBIS and AMADEUS databases, which identify firms under four categories: small, medium, large, and very large firms depending on their operating revenues, total assets and number of employees. A dummy variable for each category is created, which gets the value of 1 if a firm is in that category, and 0 otherwise.

Number of Employees: In addition to the categorical variable used for controlling size effects, the data is further controlled for the change in the size effect by adding number of employees per year in the analyses.

Industry: This variable is measured by dummy variables for each industry specified in the analyses, such as chemical, machinery, computer/electronics, electrical equipment, medical devices and software. Each dummy variable gets the value of 1 if the firm operates in that industry, and 0 otherwise.

The year dummies are also inserted in the analyses to control for time effects.

Model

In order to compare the patenting and licensing behaviors of US firms in the pre- and post-eBay case period with those of the European firms, a difference-in-difference method is adopted. One

advantage of this estimation is that it removes the biases in post-treatment period comparisons between the treatment and control group that could be the result from permanent differences between those groups, as well as biases from comparisons over time in the treatment group that could be the result of trends (Wooldridge, 2007). The difference-in-difference estimator tested in STATA 12 is specified below:

$$Y_{it} = \beta_0 + \beta_1 X_i + \beta_2 T_t + \beta_3 X_i*T_t + \beta_k(\text{control variables})_{it} + \varepsilon_{it}$$

where X_i is a dummy variable taking the value of 1 if the firm is in US (treated), else 0; T_t is a dummy variable taking the value of 1 in the post-treatment period (2007-2010) and 0 in the pre-treatment period (2001-2005), omitting year 2006 in which the US Supreme Court upheld its decision on eBay v. MercExchange case. The coefficient of β_3 gives the treatment effect, namely, the impact of the court decisions in the post-eBay period on US firms patenting and out-licensing behaviors. Since the dependent variables are count data with non-negative integers, a log transformation is used in the fixed-effects (within) regressions in panel data analyses. Fixed-effects (within) OLS regression (i.e. xtreg) is preferred because of the short panel (i.e. many individual units and few time periods) characteristic of the dataset. Fixed-effect estimation with nonlinear panel models (e.g. xtpoisson, xtnbreg) is not consistent in short panels due to incidental parameters problem.

RESULTS

Descriptive Statistics

The descriptive statistics of the data are depicted in Table-1. According to the sampled data, on average firms file 0.35 patent applications per year with a wide range from 0 applications to 2584

applications per year. Whereas, most of the firms in the data do not engage in out-licensing activities at all which results in 0.001 average number of licensing agreements per year. The maximum number of out-licensing agreements made in a year is 17. On average, the operating revenue of the sample firms is $13.7 million, and the average number of employees is 37. 18.4% of the observations are constituted of US firms, 63% of German firms and 18.6% of Swiss firms. While small firms comprise 66.4% of the sample, medium sized firms are 24.9% and large and very large firms add up to 8.8% of the total sample. Software industry has the highest representation in the data with 44.2%, it is followed by machinery industry (19.5%) and computer/electronics industry (13.5%), while chemical industry has the lowest representation by 7.1% of the total observations.

Table-1 about here

Table-2 displays the correlations between variables. It is shown that the control variables are not highly correlated to the dependent variables. The highest correlation is between small and medium sized firms with -.809. Moreover, German firms are negatively correlated with US firms (-.619) and Swiss firms (-.625). Also, number of employees is positively correlated with the operating revenue (0.704).

Table-2 about here

Regression Results

Table-3 presents the panel data regression results for the difference-in-difference estimations with fixed effects model. To test the hypotheses, the post-eBay case period is interacted with US firm dummy. The interaction term provides the impact of the treatment effect on treated firms in the post-treatment period. In Model-1, the results show that the interaction term is negative and significant ($p<0.01$), which confirms the hypothesis that upon the weakening of IP enforcement, in the post-eBay case period the US firms' patent applications have decreased (Hypothesis 1a) compared to those of European firms. The results on the main effects of the Supreme Court's eBay decision on follow-on patenting activities are in favor of 'innovation stimulation' hypothesis, rejecting 'innovation deterrence' hypothesis. Model-2 presents the results for out-licensing agreements. It shows that the interaction term is negative and significant ($p<0.01$), supporting Hypothesis 2, which asserts that in the post-eBay period the weakening of IP enforcement is negatively associated with out-licensing activities of US firms. Therefore, on average, US firms' patenting and out-licensing activities have declined upon the weakening of IP enforcement.

Table-3 about here

In order to make a finer grain analysis of the data and have a better understanding of the factors influencing US firms' patenting applications and out-licensing agreements, the data is reexamined through various subsamples. First, the sample is splitted depending on the firm size to analyze the size effects on firms' patenting and licensing activities. The split sample analyses are depicted in Table-4. In Model 1-4, the results show that the treatment effect is a negative and significant ($p<0.01$) for all firm sizes which suggest that the US firms' patent applications have decreased regardless of firm size in the post-eBay period. In addition, split sample analyses on out-licensing

agreements depict a different pattern. As it is seen in Model 5-8, for small and medium sized firms, the volume of out-licensing agreements has dropped in the post-eBay period, the interaction term is negative and significant ($p<0.01$ and $p<0.05$, respectively). However, there is no significant change in the volume of out-licensing agreements for large and very large firms.

Table-4 about here

Second, the sample is splitted depending on the industry the firms operate in to analyze the industry level variance in firms' patenting and licensing activities. The split sample analyses are presented in Table-5. Model 1-6 show the results for number of patent applications. It is seen that the treatment effect is negative and significant ($p<0.01$) for all industries, evidencing that the US firms' patent applications have dropped in all IP-intensive industries. A similar pattern is observed for US firms' licensing agreements as well. Model 7-12 present that, except the medical devices industry, the out-licensing activities of US firms have decreased in all IP-intensive industries during the post-eBay period.

Table-5 about here

Third, in order to check which type of firms would be affected the most from the weakening of IP enforcement, a subsample of upstream 'technology providers' (i.e. fabless semiconductors, system designers and biotech firms) are identified[5]. This group of firms is argued to be severely affected by the Supreme Court's eBay case decision (Davis, 2008; Diessel, 2007; Grab, 2006; Tang, 2006).

[5] The data sources are GSA-Global Semiconductor Alliance directory for fabless semiconductor firms, Bio-Biotechnology Industry Organization directory for biotech firms and BoogarLists for system design firms in electronics.

The impact of the weakening of IP enforcement on the US upstream technology providers is tested in comparison to the US downstream manufacturers. Table-6 shows the analysis results. Model 1 and 2 are comparing the US upstream technology providers with the rest of the US firms, while Model 3 and 4 are comparing the US upstream technology providers with the rest of the US firms within the same 6-digit NAICS industry classification. The treatment effect technology providers is negative but insignificant for patent applications; while its impact on out-licensing activities is negative and significant ($p<0.01$) in both comparisons. These results indicate that the decrease in patent applications is at the same level for US technology providers and US downstream manufacturers. However, US technology providers face a sharper decline in their out-licensing activities in the post-eBay case period.

Table-6 about here

Fourth, the data is further analyzed to see the impact of the weakening of IP enforcement on European firms which were '*heavily patenting in US'* before the Supreme Court's eBay decision. If the Supreme Court's decision is influencing all US patentees, these firms also should have been affected similar to the US firms. A subsample of European firms which had above average ($n\geq5$) yearly patent applications in US before the Supreme Court's eBay decision are identified as 'heavily patenting in US' and compared to the rest of European firms. Table-7 presents the analysis results. Model 1 shows that European firms 'heavily patenting in US' have decreased their patent applications in US in the post-eBay period. Yet, there is no significant volume difference between 'heavy US patenters' and rest of the European firms in their rest of the world patent applications (Model 2). Furthermore, Model 3 presents that the out-licensing agreements of 'heavy US

patenters' had a sharper decline compared to the rest of European firms. These results indicate that European firms 'heavily patenting in US' are affected similar to US firms in the post-eBay period.

Table-7 about here

Lastly, in order to analyze the potential mediating role of patenting activities on the relationship between the strength of IP enforcement and firms' out-licensing activities, a hierarchical mediation model is employed. Table-8 shows the hierarchical mediation analysis results. Model 1 and 2 shows that strength of IP enforcement has a direct negative impact on both patent applications and out-licensing activities ($p<0.01$). Moreover, patenting activities have a direct positive impact on out-licensing activities ($p<0.01$) (Model 3). Model 4 shows that both the positive impact of patent applications and the negative impact of strength of IP enforcement on out-licensing activities remain significant ($p<0.01$), suggesting a partial mediation. To better understand how much of the total effect is mediated, a Sobel-Goodman mediation test is employed. The results indicate that 96.05% of the total effect is mediated (Table-9). The results of these analyses are interpreted and policy implications are presented in the discussion section.

Table-8 about here

Table-9 about here

DISCUSSION AND CONCLUSION

This study examines the impact of IP enforcement on firms' patenting and out-licensing activities. In doing so, a recent shift in the US patent policy reflected in an exemplary Supreme Court decision is exploited to present how the weakening of IP enforcement affects the volume of patent applications and out-licensing agreements of US firms in the IP-intensive industries. Comparing to a control group of European firms (i.e. German and Swiss), it is shown that in the post-eBay period, US firms have decreased their patenting and out-licensing activities on average. However, although the number of patent applications has decreased regardless of firm size, the decline in out-licensing agreements is more pronounced for small and medium sized firms. Moreover, US firms' patent applications and out-licensing agreements have diminished in all IP-intensive industries, except medical devices industry, which, despite having a decline in patenting, shows no significant decrease in out-licensing activities. In addition, the reduction in patent applications is at the same level for upstream US technology providers and downstream US manufacturers, while technology providers have encountered a sharper decline in out-licensing activities. Besides, European firms 'heavily patenting in US' before the Supreme Court's decision are impacted similar to the US firms, i.e. showing decrease in their US patent applications and overall decrease in their patenting activities. Finally, the impact of IP enforcement on out-licensing activities is found to be mediated by patenting activities.

The results of this study are interpreted as follows. The decrease in patenting and licensing activities of US firms in the post-eBay period points to the fact that, the weakening of IP enforcement triggers a disincentive for firms to file patents and a reluctance to engage in technology trade. In line with the prior literature highlighting the benefits of a strong IP system (Arora et al., 2001; Gans & Stern, 2000; Hall & Ziedonis, 2001; Kitch, 1977; Merges & Nelson, 1990, 1994) in facilitating firms' incentives to innovate and engage in IP trade in the market for

technology, and encouraging further investment in R&D with commercial potential; the weakening of IP enforcement results in a decreased number of patenting and out-licensing activities on average. In support of the 'innovation stimulation' hypothesis, the result of this study also imply that the so-called patent hold-up and royalty stacking problems which are argued to stifle innovation (Cockburn, MacGarvie & Muller, 2010; Lemley & Shapiro, 2006; 2007) are rather sporadic than pervasive (Denicolo, et.al.,2008). In addition, the split sample analyses help to improve our understanding of which type of firms are more dependent on the strength of the patent system and severely affected by the shift in IP enforcement. Although the Supreme Court's eBay decision is associated with a decrease in patenting activities for all sizes of firms, the decline in out-licensing agreements is more pronounced for small and medium sized firms. This result suggests that small and medium sized firms, which typically lack alternative mechanisms to protect their inventions from imitation, i.e. co-specialized complementary assets (Teece, 1986), rely more heavily on the strength of the IP system. As the probability of succeeding in patent assertion decreases in the post-eBay period, the risk of expropriation increases for the small and medium sized licensors. The inflated risk of expropriation may pose disincentives for these firms to out-license their inventions (Arora and Fosfuri, 2003). Furthermore, as the strength of IP enforcement has weakened, it may become harder for these firms to negotiate for a license agreement with potential infringers. Due to the decreased bargaining power of the licensor, the potential licensee may refrain from an ex ante licensing agreement with the hope of challenging the licensor's patents in the court (Davis, 2008; Mulder, 2007; Tang, 2006). However, for large firms the weakening of IP enforcement may not pose a big threat on out-licensing activities, due to the availability of engaging in cross-licensing agreements for large patent portfolios. Cross-licensing agreements are seen as alternative mechanisms to prevent litigations (Ziedonis, 2004) and gain access to complementary patent portfolios.

This study also presents that US firms' patent applications have declined in all IP-intensive industries. Although the earlier research shows that, firms' motives to patent vary by industry (Cohen, et. al., 2000), this research suggests that the diminution in IP strength impacts all IP-intensive industries' motives detrimentally. Moreover, the upstream technology providers in these IP-intensive industries appear as the group that is affected the most upon a shift in the IP enforcement. Technology providers, due to their business model, vertically specialize and focus on technology licensing rather than downstream product manufacturing. For these firms a strong IP system is essential to vertically disintegrate and operate as technology providers to downstream manufacturers (Arora et al., 2001; Hall and Ziedonis, 2001). Building on the earlier arguments it can be said that due to higher risk of expropriation and lower bargaining power (Arora and Fosfuri, 2003; Davis, 2008; Mulder, 2007; Tang, 2006), out-licensing activities of upstream technology providers are severely impacted in the post-eBay period.

The results of this study have also some policy implications. While the US patent system is based on a balancing principle between patent exclusivity and competition policy, the results indicate that the shift in the strength of IP enforcement triggered by the Supreme Court's eBay case decision should be interpreted as an under-compensation of the patentees which reflected in lesser incentives to patent and out-license. More importantly, this shift does not affect all firms with the same intensity. Small and medium sized firms and upstream technology providers appear to be impacted the most. These results point to the importance of taking into account firm size and business model effects in stimulating innovation and addressing problems in the patent system.

This study also has some limitations. First, although this research shows that the weakening of IP enforcement has an adverse impact on both patenting and out-licensing activities of the firms, it

does not theorize whether these results imply an overall decrease in incentives to innovate or a shift from patenting to alternative mechanisms of protection; i.e. secrecy, lead time, investment in co-specialized complementary assets etc. Future studies can extend this line of research by testing the impact of IP strength on alternative mechanisms of protection. Second, this study exploits a rich dataset of firm-patent matching per year, yet it lacks patent-license matching information with royalty rates. Further research is needed on patent-license matching information to have a finer grained understanding of how the licensors' bargaining power have decreased upon the diminution in IP strength reflected in royalty rates. It is hoped that this research paves the way to refine future theorizing on these lines of research.

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APPENDIX

Table-1 Descriptive Statistics

Variables	Observations	Mean	Std. Dev.	Min	Max
Patent Applications	1455309	.349	10.389	0	2584
Out-licensing activities	1455336	.001	.050	0	17
Operating Revenue	1455336	13656.54	629880.5	-1838875	1.82e+08
Number of Employees	1455336	36.954	1617.806	0	477100
US	1455336	.184	.387	0	1
Germany	1455336	.630	.483	0	1
Switzerland	1455336	.186	.390	0	1
Small firms	1455336	.664	.472	0	1
Medium firms	1455336	.249	.432	0	1
Large firms	1455336	.064	.244	0	1
Very large firms	1455336	.024	.152	0	1
Chemical Industry	1455336	.071	.256	0	1
Machinery Industry	1455336	.195	.396	0	1
Computer/Electronics Industry	1455336	.135	.342	0	1
Electrical Equipment Industry	1455336	.051	.219	0	1
Medical Devices Industry	1455336	.075	.263	0	1
Software Industry	1455336	.442	.497	0	1

Table-2 Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Patent Applications	1.000																
2	Out-licensing	0.060*	1.000															
3	Operating Revenue	0.369*	0.058*	1.000														
4	# of Employees	0.306*	0.053*	0.704*	1.000													
5	US	0.047*	0.025*	0.025*	0.020*	1.000												
6	Germany	-0.027*	-0.017*	-0.013*	-0.010*	-0.619*	1.000											
7	Switzerland	-0.014*	-0.004*	-0.008*	-0.008*	-0.227*	-0.625*	1.000										
8	Small firms	-0.041*	-0.018*	-0.030*	-0.030*	-0.286*	0.106*	0.153*	1.000									
9	Medium firms	-0.012*	-0.005*	-0.011*	-0.009*	0.120*	-0.017*	-0.098*	-0.809*	1.000								
10	Large firms	0.009*	0.006*	0.001	0.004*	0.209*	-0.105*	-0.078*	-0.366*	-0.150*	1.000							
11	Very large firms	0.148*	0.062*	0.122*	0.113*	0.211*	-0.113*	-0.069*	-0.218*	-0.090*	-0.041*	1.000						
12	Chemical Industry	0.016*	0.031*	0.024*	0.014*	0.120*	-0.079*	-0.021*	-0.097*	0.022*	0.084*	0.105*	1.000					
13	Machinery Industry	-0.002*	-0.005*	0.001	-0.001	0.068*	0.023*	-0.096*	-0.182*	0.153*	0.082*	-0.005*	-0.136*	1.000				
14	Computer/Electronics	0.030*	0.002*	0.009*	0.013*	0.167*	-0.103*	-0.038*	-0.126*	0.075*	0.064*	0.077*	-0.109*	-0.195*	1.000			
15	Electrical Equipment	0.003*	-0.001	-0.001	0.003*	0.052*	-0.018*	-0.029*	-0.082*	0.056*	0.046*	0.022*	-0.064*	-0.114*	-0.091*	1.000		
16	Medical Devices	-0.002*	-0.001	-0.004*	-0.003*	0.009*	0.015*	-0.028*	0.040*	-0.025*	-0.028*	-0.009*	-0.079*	-0.140*	-0.113*	-0.066*	1.000	
17	Software Industry	-0.027*	-0.012*	-0.016*	-0.015*	-0.231*	0.063*	0.152*	0.319*	-0.221*	-0.162*	-0.104*	-0.246*	-0.438*	-0.352*	-0.205*	-0.253*	1.000

Table-3 Results of Fixed-effects (within) Estimations for Patenting and Out-licensing Activities

Comparison of US firms with European firms before and after eBay		
VARIABLES	(1) Patent Applications	(2) Out-licensing Agreements
Post-eBay Period*US firm	-0.0339***	-0.000920***
	(0.00108)	(0.000117)
Post-eBay Period	-0.000281	0.000788
	(0.00703)	(0.000762)
Cumulative Patent App	-0.000104***	-6.53e-06***
	(6.09e-06)	(6.61e-07)
Operating Revenue	-3.49e-09***	-8.98e-10***
	(9.14e-10)	(9.91e-11)
Number of Employees	2.43e-06***	3.27e-07***
	(4.23e-07)	(4.59e-08)
Profit Margin	0.00119***	-4.15e-05***
	(8.50e-05)	(9.22e-06)
Firm Age	-0.000936	-0.000107
	(0.000821)	(8.90e-05)
Constant	0.0635***	0.00277***
	(0.00976)	(0.00106)
Year FE	YES	YES
Firm FE	YES	YES
Observations	976,207	976,207
R-squared	0.003	0.000
Number of company_id	136,920	136,920

NOTE: Standard errors in parentheses, DVs log-transformed, country, size and industry dummies inserted. (*** p<0.01, ** p<0.05, * p<0.1)

Table-4 Results of Fixed-effects (within) Estimations for Firm Size Effects on Patenting and Out-licensing Activities

	(1)	(2)	(3)	(4)
	Small	Medium	Large	Very Large
VARIABLES	Patent Applications	Patent Applications	Patent Applications	Patent Applications
Post-eBay Period*US firm	-0.0264***	-0.0150***	-0.0463***	-0.133***
	(0.000984)	(0.00180)	(0.00557)	(0.0140)
Post-eBay Period	-0.00688	-0.00938	0.0234	0.187*
	(0.00470)	(0.0132)	(0.0466)	(0.109)
Cumulative Patent App	-7.92e-05***	-0.00512***	-0.00318***	-6.28e-05***
	(6.65e-06)	(0.000114)	(0.000179)	(1.84e-05)
Operating Revenue	-5.86e-08***	-1.67e-08	-3.44e-09	-5.89e-09**
	(6.07e-09)	(1.46e-08)	(5.12e-09)	(2.58e-09)
Number of Employees	1.02e-05***	4.41e-05***	3.84e-05***	1.74e-06
	(3.29e-06)	(6.21e-06)	(1.06e-05)	(1.15e-06)
Profit Margin	0.000454***	0.00105***	0.000271	0.00209***
	(0.000117)	(0.000202)	(0.000318)	(0.000341)
Firm Age	0.000102	0.000412	-0.00130	-0.0242*
	(0.000549)	(0.00155)	(0.00544)	(0.0127)
Observations	554,750	306,865	83,906	30,686
R-squared	0.003	0.010	0.009	0.013
Number of company_id	84,655	38,510	10,048	3,707
	(5)	(6)	(7)	(8)
	Small	Medium	Large	Very Large
	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements
Post-eBay Period*US firm	-0.000320***	-0.000301**	-0.000181	-0.00313
	(8.86e-05)	(0.000120)	(0.000466)	(0.00252)
Post-eBay Period	0.000407	0.000151	-0.00250	0.0222
	(0.000424)	(0.000883)	(0.00390)	(0.0195)
Cumulative Patent App	-2.06e-07	-0.000141***	6.25e-06	-6.15e-06*
	(5.99e-07)	(7.63e-06)	(1.49e-05)	(3.30e-06)
Operating Revenue	0	-6.75e-09***	-2.13e-10	-9.36e-10**
	(5.47e-10)	(9.76e-10)	(4.28e-10)	(4.64e-10)
Number of Employees	4.35e-08	4.83e-06***	1.06e-07	3.83e-07*
	(2.97e-07)	(4.14e-07)	(8.87e-07)	(2.07e-07)
Profit Margin	3.18e-05***	-5.26e-05***	-4.50e-05*	-4.83e-05
	(1.05e-05)	(1.35e-05)	(2.66e-05)	(6.14e-05)
Firm Age	-4.88e-05	-1.34e-05	0.000217	-0.00320
	(4.94e-05)	(0.000103)	(0.000455)	(0.00228)
Observations	554,750	306,865	83,906	30,686
R-squared	0.003	0.010	0.009	0.013
Number of company_id	84,655	38,510	10,048	3,707

NOTE: Standard errors in parentheses, DVs log-transformed, country, industry and year dummies inserted (*** p<0.01, ** p<0.05, * p<0.1)

Table-5 Results of Fixed-effects (within) Estimations for Industry Effects on Patenting and Out-licensing Activities

	Chemical	Machinery	Computer	Electric	Medical D.	Software
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Patent Applications	Patent Applications	Patent Applications	Patent Applications	Patent Applications	Patent Applications
Post-eBay Period*US firm	-0.0452***	-0.0226***	-0.0511***	-0.0196***	-0.0185***	-0.0346***
	(0.00467)	(0.00222)	(0.00325)	(0.00515)	(0.00380)	(0.00134)
Post-eBay Period	0.0250	0.00473	0.00556	-0.0353	0.0207	-0.00628
	(0.0358)	(0.0162)	(0.0250)	(0.0385)	(0.0242)	(0.00621)
Cumulative Patent App	-8.74e-05***	-0.000254***	-0.000112***	2.44e-05	0.000151**	-0.000501***
	(2.49e-05)	(2.49e-05)	(9.80e-06)	(4.90e-05)	(6.56e-05)	(3.20e-05)
Operating Revenue	-1.58e-08***	1.12e-08***	2.06e-08***	-1.72e-08**	7.47e-08***	1.38e-08***
	(2.01e-09)	(2.38e-09)	(2.57e-09)	(7.91e-09)	(1.68e-08)	(3.33e-09)
Number of Employees	5.25e-06***	2.20e-06*	-4.30e-06***	1.26e-05***	-2.14e-05***	-7.64e-07
	(1.10e-06)	(1.15e-06)	(1.01e-06)	(2.26e-06)	(4.54e-06)	(8.68e-07)
Profit Margin	0.00157***	0.00134***	0.00130***	0.000217	0.000417	0.00126***
	(0.000283)	(0.000239)	(0.000206)	(0.000456)	(0.000312)	(0.000103)
Firm Age	-0.00642	-0.000737	-0.00248	0.00440	-0.00308	-0.000150
	(0.00418)	(0.00190)	(0.00292)	(0.00450)	(0.00283)	(0.000724)
Observations	74,230	216,458	150,385	55,001	80,782	362,585
R-squared	0.011	0.003	0.006	0.002	0.001	0.005
Number of company_id	10,096	28,486	19,971	7,145	10,740	55,789
	Chemical	Machinery	Computer	Electric	Medical D.	Software
	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements	Out-licensing Agreements
Post-eBay Period*US firm	-0.00246**	-0.000377***	-0.00106***	-0.00110***	-0.000368	-0.000491***
	(0.000991)	(0.000114)	(0.000300)	(0.000333)	(0.000380)	(0.000111)
Post-eBay Period	0.0120	0.000316	0.000457	-0.000497	-0.000760	-0.000212
	(0.00759)	(0.000838)	(0.00231)	(0.00249)	(0.00242)	(0.000515)
Cumulative Patent App	5.27e-06	6.04e-06***	-1.02e-05***	-1.33e-07	-2.04e-05***	-7.57e-05***
	(5.29e-06)	(1.28e-06)	(9.06e-07)	(3.17e-06)	(6.57e-06)	(2.66e-06)
Operating Revenue	-2.10e-09***	-4.57e-10***	1.30e-09***	2.15e-10	2.05e-09	-2.87e-09***
	(4.26e-10)	(1.23e-10)	(2.38e-10)	(5.12e-10)	(1.68e-09)	(2.76e-10)
Number of Employees	2.65e-07	3.20e-07***	-2.21e-08	-6.18e-08	-4.64e-07	1.16e-06***
	(2.34e-07)	(5.91e-08)	(9.32e-08)	(1.46e-07)	(4.55e-07)	(7.20e-08)
Profit Margin	-0.000187***	1.35e-05	1.74e-05	7.54e-05**	-9.36e-05***	-4.60e-05***
	(6.00e-05)	(1.23e-05)	(1.91e-05)	(2.95e-05)	(3.13e-05)	(8.54e-06)
Firm Age	-0.00146*	-4.09e-05	-0.000145	0.000106	8.54e-05	2.94e-05
	(0.000886)	(9.79e-05)	(0.000270)	(0.000291)	(0.000283)	(6.01e-05)
Observations	74,230	216,458	150,385	55,001	80,782	362,585
R-squared	0.001	0.001	0.001	0.001	0.001	0.004
Number of company_id	10,096	28,486	19,971	7,145	10,740	55,789

Table-6 Results of Fixed-effects (within) Estimations for Main Effects on Technology Providers' Patenting and Out-licensing Activities

	US Technology Providers v. Rest of US firms		US Technology Providers v. Rest of US firms within industry	
VARIABLES	(1) Patent Applications	(2) Out-licensing Agreements	(3) Patent Applications	(4) Out-licensing Agreements
Post-eBay Period*US Technology Provider	-0.00923	-0.00601***	-0.00610	-0.00567***
	(0.0140)	(0.00168)	(0.0145)	(0.00188)
Post-eBay Period	-0.0724***	-0.00164***	-0.0862***	-0.00197***
	(0.00320)	(0.000383)	(0.00387)	(0.000500)
Cumulative Patent App	-0.000104***	-6.15e-06***	-9.01e-05***	-6.68e-06***
	(1.21e-05)	(1.44e-06)	(1.31e-05)	(1.69e-06)
Operating Revenue	-1.39e-10	-1.56e-09***	1.08e-10	-2.09e-09***
	(1.80e-09)	(2.16e-10)	(2.03e-09)	(2.61e-10)
Number of Employees	6.43e-07	7.20e-07***	-1.31e-06	7.93e-07***
	(8.21e-07)	(9.83e-08)	(9.60e-07)	(1.24e-07)
Profit Margin	0.00129***	-4.51e-05*	0.00156***	-4.59e-05
	(0.000199)	(2.38e-05)	(0.000219)	(2.83e-05)
Observations	216,607	216,607	159,530	159,530
R-squared	0.006	0.001	0.007	0.001
Number of company_id	28,148	28,148	21,134	21,134

NOTE: Standard errors in parentheses, DVs log-transformed, year, size and industry dummies inserted. (*** p<0.01, ** p<0.05, * p<0.1)

Table-7 Results of Fixed-effects (within) Estimations for Main Effects on 'Heavy US Patenter' European Firms' Patenting and Out-licensing Activities

Comparison of European Firms 'Heavily Patenting in US' v. Rest of European Firms			
VARIABLES	(1) European Firms' Patent Applications in US	(2) European Firms' Patent Applications (rest of the world)	(3) European Firms' Out-licensing Activities worldwide
Post-eBay Period*Heavy US Patenter	-0.367***	-0.00621	-0.00280***
	(0.00312)	(0.00557)	(0.000482)
Post-eBay Period	0.0102***	-0.0105**	0.000384
	(0.00279)	(0.00497)	(0.000431)
Operating Revenue	-1.21e-08***	-1.65e-08***	1.94e-09***
	(6.36e-10)	(1.13e-09)	(9.14e-11)
Number of Employees	7.89e-06***	7.86e-06***	-1.75e-06***
	(3.47e-07)	(6.19e-07)	(4.90e-08)
Profit Margin	0.000177***	0.000775***	-1.68e-05**
	(4.53e-05)	(8.08e-05)	(7.00e-06)
Firm Age	-0.00119***	0.00131**	-4.59e-05
	(0.000325)	(0.000580)	(5.03e-05)
Observations	762,976	762,969	762,985
R-squared	0.023	0.002	0.002
Number of company_id	109,148	109,148	109,149

NOTE: Standard errors in parentheses, DVs log-transformed, year, size and industry dummies inserted. (*** p<0.01, ** p<0.05, * p<0.1)

Table-8 Results of Fixed-effects (within) Estimations for Hierarchical Mediation Model

VARIABLES	(1) Patent Applications	(2) Out-licensing Agreements	(3) Out-licensing Agreements	(4) Out-licensing Agreements
Patent Applications			0.00134***	0.00131***
			(0.000118)	(0.000118)
Post-eBay Period*US firm	-0.0337***	-0.000919***		-0.000875***
	(0.00107)	(0.000116)		(0.000117)
Post-eBay Period	-0.00832***	-0.000118	-0.000326***	-0.000107
	(0.000923)	(0.000100)	(9.59e-05)	(0.000100)
Cumulative Patent App	-0.000105***	-6.53e-06***	-6.56e-06***	-6.39e-06***
	(6.11e-06)	(6.63e-07)	(6.62e-07)	(6.63e-07)
Operating Revenue	-3.49e-09***	-8.98e-10***	-8.92e-10***	-8.94e-10***
	(9.16e-10)	(9.94e-11)	(9.94e-11)	(9.94e-11)
Number of Employees	2.43e-06***	3.27e-07***	3.17e-07***	3.24e-07***
	(4.24e-07)	(4.60e-08)	(4.60e-08)	(4.60e-08)
Profit Margin	0.00118***	-4.13e-05***	-4.31e-05***	-4.29e-05***
	(8.50e-05)	(9.22e-06)	(9.23e-06)	(9.23e-06)
Observations	979,897	979,897	979,897	979,897
R-squared	0.003	0.000	0.001	0.001
Number of company_id	137,330	137,330	137,330	137,330

NOTE: Standard errors in parentheses, DVs log-transformed, year, size and industry dummies inserted. (*** p<0.01, ** p<0.05, * p<0.1)

Table-9 Results of Sobel-Goodman Mediation Test

```
. sgmediation lnewoutlicense, mv(lnewpatapp) iv(interaction)

Model with dv regressed on iv (path c)

      Source |       SS       df       MS              Number of obs = 1061072
-------------+------------------------------           F(  1,1061070) =  142.68
       Model |  .088012761     1  .088012761           Prob > F      =  0.0000
    Residual |  654.5095211061070  .000616839           R-squared     =  0.0001
-------------+------------------------------           Adj R-squared =  0.0001
       Total |  654.5975331061071  .000616922           Root MSE      =  .02484

------------------------------------------------------------------------------
lnewoutlic~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 interaction |   .0009568   .0000801    11.95   0.000     .0007998    .0011138
       _cons |      .0005   .0000254    19.66   0.000     .0004502    .0005498
------------------------------------------------------------------------------

Model with mediator regressed on iv (path a)

      Source |       SS       df       MS              Number of obs = 1061072
-------------+------------------------------           F(  1,1061070) =17410.84
       Model |  2499.87769     1  2499.87769           Prob > F      =  0.0000
    Residual |  152350.1921061070   .14358166          R-squared     =  0.0161
-------------+------------------------------           Adj R-squared =  0.0161
       Total |  154850.0691061071  .145937519          Root MSE      =  .37892

------------------------------------------------------------------------------
  lnewpatapp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 interaction |   .1612524   .0012221   131.95   0.000     .1588572    .1636476
       _cons |   .0673691   .0003879   173.67   0.000     .0666088    .0681294
------------------------------------------------------------------------------

Model with dv regressed on mediator and iv (paths b and c')

      Source |       SS       df       MS              Number of obs = 1061072
-------------+------------------------------           F(  2,1061069) = 4113.34
       Model |  5.03617785     2  2.51808892           Prob > F      =  0.0000
    Residual |  649.5613561061069  .000612176          R-squared     =  0.0077
-------------+------------------------------           Adj R-squared =  0.0077
       Total |  654.5975331061071  .000616922          Root MSE      =  .02474

------------------------------------------------------------------------------
lnewoutlic~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  lnewpatapp |    .005699   .0000634    89.90   0.000     .0055748    .0058233
 interaction |   .0000378   .0000804     0.47   0.638    -.0001199    .0001955
       _cons |    .000116   .0000257     4.52   0.000     .0000657    .0001664
------------------------------------------------------------------------------

Sobel-Goodman Mediation Tests

                    Coef          Std Err      Z          P>|Z|
Sobel              .00091898    .00001237    74.3       0
Goodman-1 (Aroian) .00091898    .00001237    74.3       0
Goodman-2          .00091898    .00001237    74.3       0

                    Coef      Std Err    Z          P>|Z|
a coefficient   =  .161252   .001222    131.95          0
b coefficient   =  .005699   .000063    89.905          0
Indirect effect =  .000919   .000012    74.298          0
  Direct effect =  .000038    .00008   .470052    .638318
   Total effect =  .000957    .00008    11.945          0

Proportion of total effect that is mediated:  .96047742
Ratio of indirect to direct effect:           24.301989
Ratio of total to direct effect:              25.301989
```

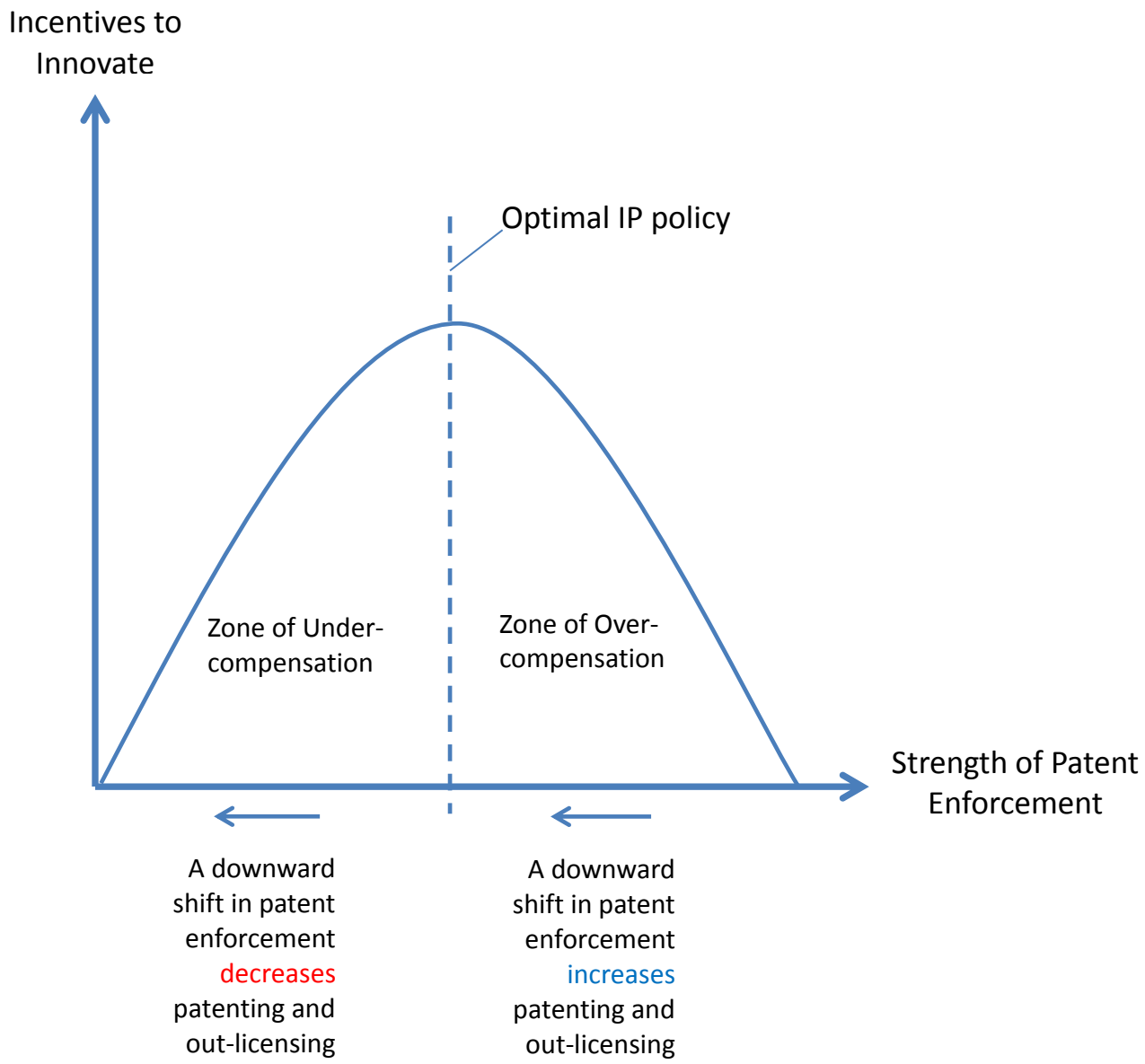

Figure 1- Optimal IP Policy

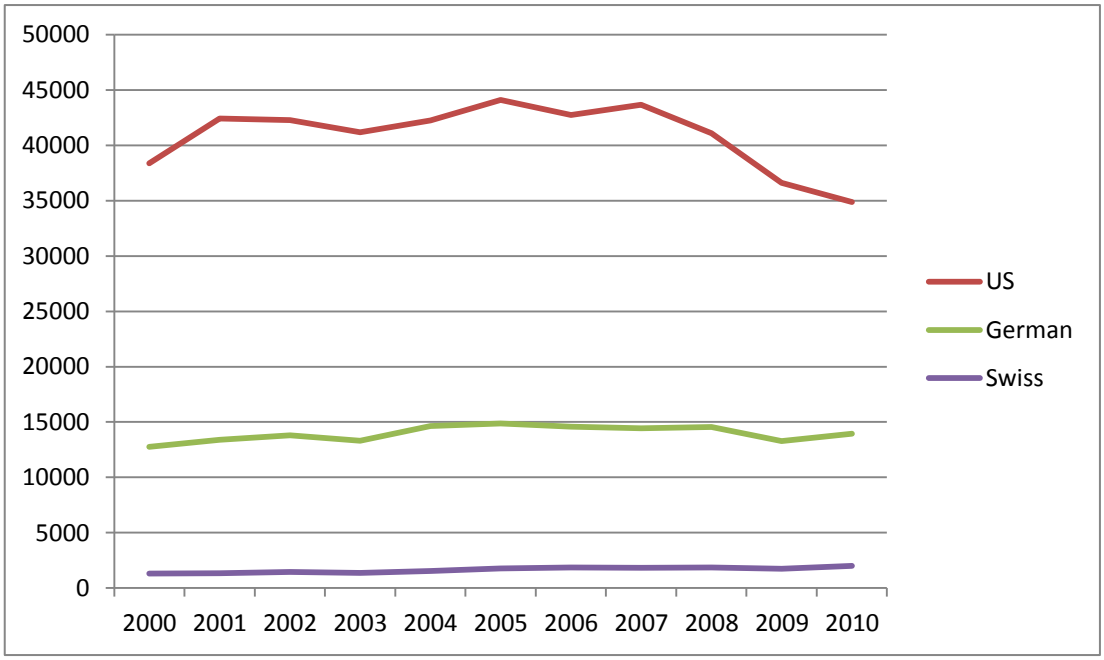

Figure-2 Worldwide Patent Applications

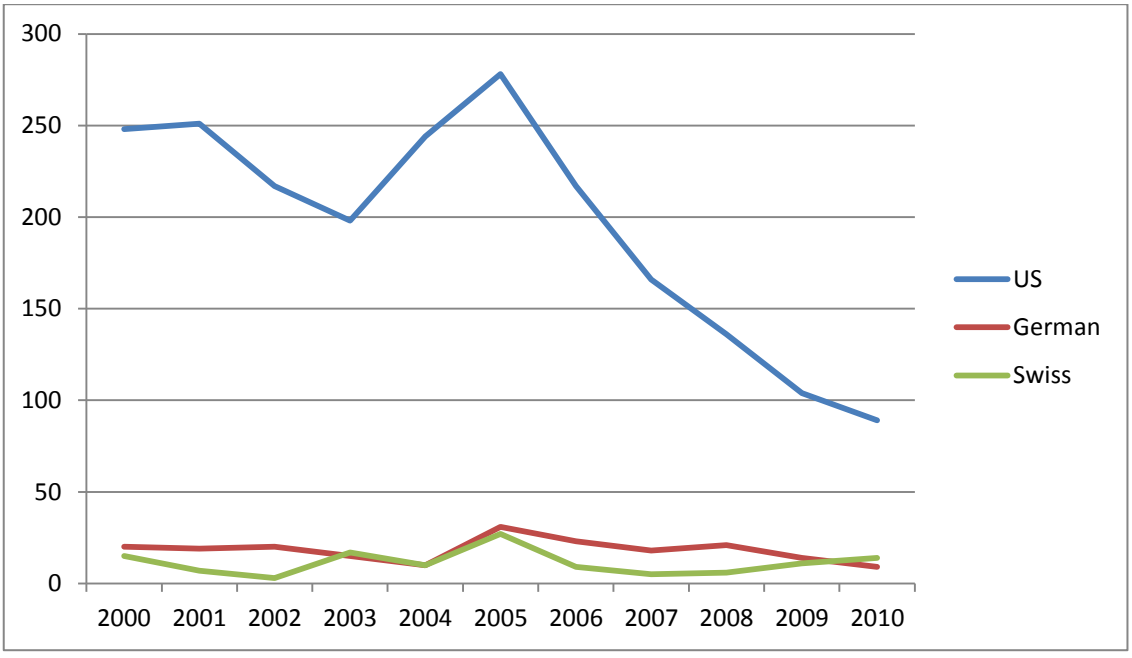

Figure-3 Worldwide Out-licensing Activities

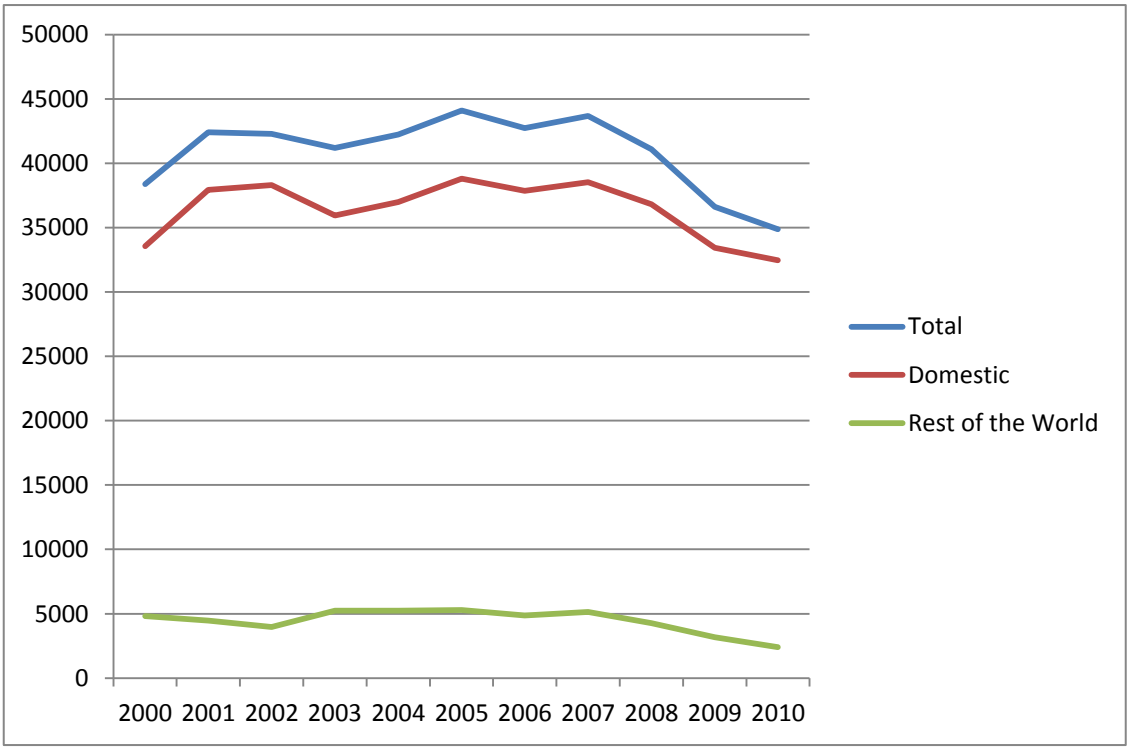

Figure-4 Decomposition of US Firms' Patent Applications

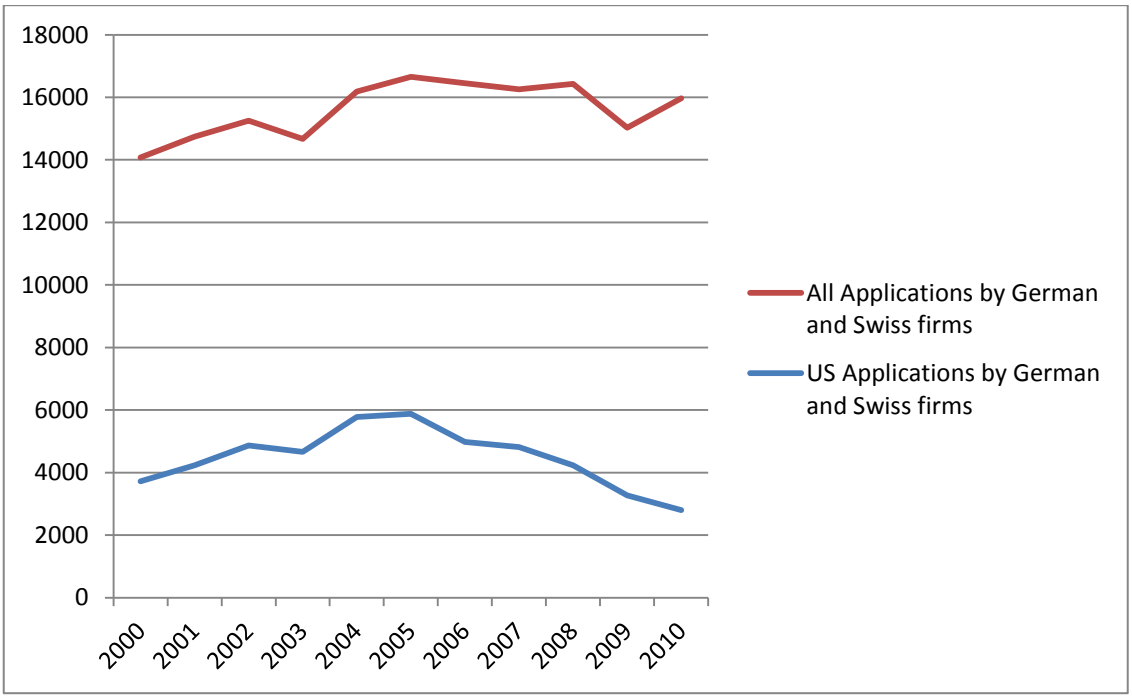

Figure-5 Decomposition of European Firms' Patent Applications