Intellectual Property Rights (IPR) Regime and Innovation in a Developing Country Context: Evidence from the 1986 IPR Reform in Korea

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Abstract

Intellectual Property Rights (IPR) system is one of the major institutions for incentivizing innovation. However, a strong IPR regime does not necessarily encourage innovation every time. This is because a variety of factors come into play in configuring the ways the IPR system interacts with the dynamics of innovation. In the present study, we examine whether different degrees of absorptive capacity at the industry level bring about heterogeneous effects of a strong IPR regime on the innovation capability of innovators across different industries in developing country. Using the case of the 1986 IPR reform in Korea, which permitted patenting pharmaceutical products and copyrighting computer programs, we analyze the quality of patents produced by Korean applicants between 1982 and 1991. Our analysis finds no evidence that the IPR reform improved the innovation capability of innovators in the two aforementioned sectors, but rather affected their patenting behavior differently.

Keywords
intellectual Property Rights (IPR), absorptive capacity, innovation, developing countries

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1. INTRODUCTION

Intellectual Property Rights (IPR) system is one of the key institutions for incentivizing innovation. However, it is unclear whether a strong IPR regime always encourages innovation. This is because the relationship between the strength of an IPR regime and innovation depends on the interaction between a variety of factors and accompanying complex dynamics. Indeed, previous studies emphasize different factors and conditions that define the relationship between an IPR regime and innovation. The effects of a strong IPR regime are determined by an innovative firm's organizational structure that governs the interaction between its R&D and IPR managing divisions (Sakakibara & Branstetter, 2001). The impact of an IPR regime on innovation activities differs from one industry to the next (Moser, 2003). This is because the importance of IPR is varied across different industries (Cohen, Nelson, & Walsh, 2000). A weak IPR may drive innovation by promoting technological competitions and suitable R&D investments (Qian, 2008). However, firms strategically protect their intellectual property through knowledge internalization in the face of a weak IPR regime (Zhao, 2006).

In the context of developing countries, innovation policy makers encounter particular difficulties in designing a proper IRP policy due to complex dynamics and various factors which must be considered in understanding the relationship between an IPR regime and innovation. Since developing countries often suffer from limited infrastructure and resources for innovation activities, it becomes crucial for the policymakers to find the best mode of institutions to promote innovation effectively. When it comes to IPR systems, it is critical to recognize how the strength of an IPR regime affects the innovation capability of indigenous innovators across different industrial sectors. A strong IPR regime can be disastrous for infant industries yet advantageous for innovators capable of exploiting new opportunities generated from it.

Although previous studies present extensive discussions on how the organizational or strategic characteristics of innovators and general industrial characteristics relate to the impact of an IPR regime on innovation in developed countries, they offer little information about how the strength of an IPR regime influences the innovation capability of innovators across different industries in developing countries with different levels of absorptive capacity. Does a strong IPR regime have different effects on the innovation capability of innovators with respect to their level of absorptive capacity in developing country? The present study aims to address this question by examining the 1986 IPR reform in Korea. We believe this IPR reform is a unique case to address the research question of the present study for the following reasons. First, this unique event was particularly important in strengthening Korea's IPR regime. The reform extended the patent length from 12 to 15 years. Also, patenting new substances such as pharmaceutical products and protecting the copyrights of computer software became possible. Secondly, the Korea's pharmaceutical industry was at an early development stage whereas the computer software related industry had already seen rapid growth since 1970s. Hence, innovators in the two sectors may have built different levels of absorptive capacity. Lastly, the reform took place when Korea was still a developing economy.

For our empirical analysis, we take the quality of patents as a proxy for the innovation capability. We analyze whether the quality of patents improved differently for pharmaceuticals and computer software related patents after the reform. We have obtained the patents filed to US, Germany and UK by Korean applicants between 1982 and 1991.

Our analysis finds no empirical evidence that the Korean IPR reform enhanced the technological significance of patents in both pharmaceutical and computer software related patents. Instead, the reform seems to have affected the patenting behavior of inventors differently. Our findings contribute to the broad literature on the relationship between an IPR regime and innovation with implications for innovation policymakers in developing countries.

The remainder of the present paper is organized as follows. In section 2, we review theoretical and empirical literatures on the relationship between an IPR regime and innovation, followed by a brief history of the 1986 IPR Reform in section 3. We derive our hypotheses from these literatures in section 4. In section 5, our empirical approach tests the derived hypotheses. We then present the result in section 6, followed by further discussions in section 7. In section 8, we conclude with implications and limitations of this research.

2. LITERATURE REVIEW

The classical argument favoring a strong IPR regime (Nordhaus, 1969) underscores two different benefits of protection. It argues that knowledge has the characteristics of public goods, which means that due to its non-rivalrous and non-excludable nature, knowledge is under-produced. Inventors have enough incentives to allocate their resources on innovation only when provided with adequate protection for their inventions. The theory also argues that a strong IPR leads to a greater level of knowledge diffusion through partial disclosures of patented knowledge. In this sense, an institutional change toward stronger IPR protection may lead to both greater knowledge production and diffusion. Another stream of literature views IPR as part of a broader property rights institution, which is essential for facilitating the well-functioning market system (Besley, 1995; Stiglitz, 1989). It is argued that the benefits of IPR are not only restricted to innovation but rather contribute to the overall impact of IPR (as a property right regime) on economy (Chen & Puttitanun, 2005). In particular, poor intellectual property rights in developing countries are blamed for inadequate investments in innovative activities, because there are high transactions costs in identifying the true value of investments in innovative activities. These theories suggest that a stronger IPR offers greater incentives to invest in innovation. However, due to increasing technological sophistication and interdependencies, and the cumulative nature of knowledge in our modern industries, the relationship between the IPR strength and innovation becomes more ambiguous (Gallini, 2002). The following section presents an overview of the previous literatures on the strength of IPR and its relationship with innovation and knowledge diffusion.

2.1. IPR and Incentives to Innovate

To analyze the effects of IPR, especially in terms of how they provide an incentive to innovate, it is convenient to distinguish between the "strength of breadth" and the "patent length." The strength of breadth refers to the scope of a patent claim. The greater the breadth, the greater the legal coverage of a patented invention. Therefore, a wide patent breadth may benefit inventors since the probability of prevailing as the "infringed against a subsequent inventor" increases. However, the probability of losing as the "infringer against a previous patent holder" increases as well (O'Donoghue, Scotchmer, & Thisse, 1998), which makes a stronger IPR regime both a blessing and a curse at the same time (Gallini, 2002).

The patent length refers to the years of protection received by a patented invention. Past literatures viewed the relationship between the length of a patent and incentives to innovate as simple monotonic relationship. That is, increasing the patent length would increase the rate of innovation. However, modern theoretical literatures do not support this simple explanation (Gallini, 1992). Complicated by the effects of the patent length on the cost of limitation, an inverted-U shaped curve between the patent length and the rate of innovation is suggested (Horowitz & Edwin, 1996), which indicates that excessive patent length could hinder the overall number of innovations.

2.2. IPR and Diffusion of Knowledge

Another benefit of IPR is knowledge diffusion from patent applications. IPR facilitate knowledge diffusion via two main channels. Firstly, the process of patenting requires inventors to reveal knowledge to the public. However, this "public" knowledge, codified in the patent document, often fails to provide sufficient information about the true invention. Furthermore, inventors have an incentive to obscure their knowledge and hide their true inventions for knowledge protections out of their strategic motivations (Gallini, 2002). Especially, theses strategic motivations are heavily associated with the "patent trolling" by "non-practicing patent entities" in which patent litigations are the primary sources of their economic activities (Shapiro, 2001).

IPR could also facilitate knowledge diffusion by creating new markets. According to the new institutional economics theory (North, 1986; Williamson, 2000) on the property rights system, property rights have "transferability" characteristics. Because IPR are transferable via markets, the patented knowledge becomes more efficient in that the IPR can be utilized by more efficient users. Management literatures have elaborated on the concept of "market for technologies (Arora, Fosfuri, & Gambardella, 2001)." Provided that property rights are assigned to inventions, Arora et al. (2001) argue that technology transfers are manifested through various forms of transactions, including licensing agreements. Stronger IPR could further facilitate licensing activities because a higher appropriation level empowers a patent holder's bargaining power and lowers transaction costs. As a result, this gives inventors incentives to license out their technologies (Arora & Merges, 2004). However, weaker IPR settings could also allow diffusion of patented knowledge through "non-infringing" imitations or with licenses offered to discourage a rival's "invent-around" attempts (Gallini, 1984; Gallini & Winter, 1985). Thus, the overall impact of the strength of IPR on knowledge diffusion remains ambiguous.

2.3. Previous Empirical Literatures

The previous literatures on IPR make ambiguous predictions about the impact of strengthening IPR on innovation. The previous empirical results, as shown in Table 1, analyze different effects of IPR. Gould and Gruben (1996), Ginarte and Park (1997) and Kanwar and Evenson (2003)'s macro-analyses prove that stronger IPR enhance innovation. On the other hand, Sakakibara and Branstetter (2001) and Hall and Ziedonis (2001)'s analyses find no significant relationships. With regards to the level of economic development, Park and Ginarte (1997), Chen and Puttitanun (2005) and Kim, Lee, Park, and Choo (2012)'s analyses indicate that the level of economic development moderates the impact of IPR on innovation. On the other hand, Woo, Jang, and Kim (2015) suggest that the impacts of IPR could be varied by industries due to the unique type of knowledge distributions that are associated with these industries.

TABLE 1. Past Empirical Literatures on the Role of Strong IPR

Role of IPR	Literatures	Level of Analysis
Enhance Innovation	(Gould & Gruben, 1996)	country-level
	(Ginarte & Park, 1997)	firm-level
	(Kanwar & Evenson, 2003)	country-level
No Relation or Impede Innovation	(Kortum & Lerner, 1999)	patents
	(Sakakibara & Branstetter, 2001a)	firm-level
	(Hall & Ziedonis, 2001)	firm-level
Mixed Results	(Park & Ginarte, 1997)	country-level
	(Chen & Puttitanun, 2005)	country-level
	(Kim et al., 2012)	country-level
	(Woo et al., 2015)	industry-level

2.4. IPR and Developing Countries

As seen in Table 1, to a certain extent the ambiguities associated with an IPR regime reflect the dynamic relationship between the level of economic development and IPR's impact on innovation. Just as there are contending theories about the role of IPR, scholars disagree on a number of issues related to IPR in developing countries. In particular, the TRIPs Agreement in 1994 has proliferated both theoretical and empirical researches on the role of IPR in developing countries. The previous theories and empirical studies suggest that IPR's impact on innovation is moderated by the level of economic development (Chen & Puttitanun, 2005; Kim et al., 2012; Park & Ginarte, 1997). These literatures imply that there exists an adequate level of capacity for indigenous innovations, which is necessary for IPR to have significant effects on indigenous innovations. Implicit in this argument is that each country's innovation capacity (which may also vary across different industries) has strong influence on the way potential inventors respond to new constraints and incentive signals from an enhanced IPR regime. Therefore, a mere improvement in IPR protection may not result in an increased number of innovations. Incentives provided by an enhanced IPR do not stimulate R&D without an adequate level of absorptive capacity.

Therefore, a country's ability to exploit the benefits of an IPR reform may be related to its absorptive capacity (Cohen & Levinthal, 1990). Cohen and Levinthal (1990) originally defined absorptive capacity as an organizational ability to identify, integrate and exploit external knowledge. Since absorptive capacity is path dependent, established industries with a high level of research capabilities have greater absorptive capacity. Therefore, an industry with a higher level of absorptive capacity will be better at identifying and absorbing knowledge as well as at responding to incentives provided by an enhanced IPR. An empirical study also shows that absorptive captivity plays a significant role in increasing the elasticity of innovation with respect to international knowledge spillover (Mancusi, 2008).

3. THE 1986 IPR REFORM IN KOREA

A brief background history of the 1986 IPR Reform in Korea provides a better understanding of the historical context for empirical investigations. Since its launch in 1946, Korea's modern IPR system has undergone 16 reforms of various scales. Starting from the pre-1980s "weak" IPR regime, Korea has periodically adopted stronger IPR systems due to growing external pressures and internal demands for further incentives to innovate. Since the 1980s, US has increasingly pressured developing countries to strengthen their IPR (Allred & Park, 2007; Song, 2006). Such pressures were particularly prevalent in major exporting countries such as Japan (Sakakibara & Branstetter, 2001), Taiwan (Lo, 2011) and Korea (La Croix & Kawaura, 1996).

The 1986 IPR Reform in Korea was largely a response to the growing US pressure, which called for stronger IPR protection including the extension of property rights to pharmaceutical inventions and computer software copyrights (La Croix & Kawaura, 1996). For example, in 1985, the Regan administration ordered Section 301 investigation to review Korea's IPR regime under the Trade Act. The investigation was suspended once the two countries made an agreement on the trade issue, which involved a major IPR reform. The reform involved the introduction of pharmaceutical patents and computer software copyrights. Before the reform, only the process of innovating pharmaceutical inventions had been patented. The reform removed the "invention of drugs or drug-prescribing methods," and the "invention of materials or the uses of materials" from the list of non-patentable inventions. Before, the Korean government's rationale behind excluding pharmaceutical inventions from patentable subjects had been largely based on the principle of economic protectionism. In other words, the government had aimed to protect and nurture domestic pharmaceutical industries at an early stage until they acquired adequate research capabilities. Their dilemmas can be indirectly observed in a major business newspaper of the era. An editorial from Maeil Business Newspaper argued that because pharmaceutical patents (or drug substance patents) were very powerful forms of IPR, the reform would only benefit foreign companies. There were two reasons for this; firstly, most Korean patent activities were dominated by foreign applicants, and secondly because there was a large technological gap between domestic patents and those of foreign applicants ("Reasons to delay introduction of pharmaceutical patents before enhancing domestic research capacity Editorial," 1984). Yet, the constant pressure from the US with the threat of potential trade retaliation and a growing need for improving the country's innovative capacity ultimately led the Korean government to introduce pharmaceutical patents in December, 1986 (KIPO, 2007).

As for the introduction of computer software copyrights, the Korean government and industries had mixed feelings. On the one hand, the growing significance and economic opportunities found in the computer software industry meant that providing it with sound institutions and adequate environments became necessary. In fact, a government report from the Ministry of Science and Technology literately stated that a good institution for software copyrights was necessary in promoting Korea's software industry in the future (G. Kim, 1984). These views were shared by a number of small and medium-sized software enterprises. On the other hand, large manufacturing firms using industrial software became worried about the consequences of introducing software copyrights. Although they understood the importance of establishing a sound property rights institution, they were threatened by the potential adverse effects on many manufacturing industries such as semi-conductor, shipbuilding and engineering industries, which relied heavily upon foreign industrial software (J. Kim, 1986). Overall, although the government and industries believed that the copyrights in the software industry were vital, they also believed that the introduction of computer software copyrights in 1986 seemed too early. Amidst growing concerns, the Computer Program Protection Law was passed in December, 1986 (KIPO, 2007). The 1986 IPR Reform extended the patent length from 12 to 15 years.

We would like to underscore that the usefulness of 1986 IPR reform in investigating the impact of IPR reforms in developing countries. Although it is difficult to assess with accuracy the developmental phase of the Korean economy at that time, what is for sure is that the 1986 IPR Reform suffers little from endogeneity problems. In fact, the reform was more closely related to external shocks resulting from the increased US pressure. This contrasts sharply with the Japanese case where the majority of industries welcomed the introduction of pharmaceutical patents in the 1970s (La Croix & Kawaura, 1996).

4. HYPOTHESES DEVELOPMENT

We focus on an empirical examination of whether the 1986 IPR Reform had different effects on the innovation capability of Korean inventors across industrial sectors. In particular, we analyze the reform's impact on improving the innovation capability of Korean inventors in pharmaceuticals and computer software sectors.

The 1986 Korean IPR Reform permitted patenting new substances. New chemical compounds with specific functions became a patentable subject matter. The reform had the most significant impact on the pharmaceutical sector. This addition of new substances as a patentable subject matter had been expected as a measure to enhance the innovation capacity of the Korean pharmaceutical firms by incentivizing their R&D. As the patent law now protected new substances, pharmaceutical firms could expect better appropriability conditions for their R&D, which in turn would encourage them to engage in further innovative activities and enhance their innovation capability consequently. However, the overall impact might have been significantly limited since the Korean pharmaceutical firms were at an early stage of development in the 1980s, with a relatively low level of absorptive capacity. Even if the addition of a patentable subject matter created new market opportunities, underdeveloped absorptive capacity may not help innovators to catch the new market opportunities sufficiently (Cohen & Levinthal, 1990), which would have consequently limited the expected impact of improving the innovation capacity of the Korean inventors. This rationale formulates our first hypothesis.

H1. The 1986 Korean IPR Reform was not effective in improving the innovation capability of Korean inventors in the pharmaceutical industry.

The Korean IPR Reform in 1986 also protected the copyrights of computer programs. The importance of the protection of the computer program has been widely recognized, given the explosive growth of the personal computer market in the 1980s as well as the semiconductor industry which required an extensive use of computer program. Unlike patents, which protect original and innovative ideas, copyrights protect the "expression" of ideas contained in works (Greenhalgh & Rogers, 2010). In the case of software, copyrights protect the underlying codes. This could be a disadvantage to a copyright holder since copyrights do not protect ideas. For example, competitors can create alternative works by reconfiguring the software code written by the original inventor. However, copyrights still provide limited protection for software inventions, and we posit that the introduction of computer software copyrights had a significant impact on software-related industries. In the 1980s, many large Korean firms primarily found their market positions in electronics and semiconductor sectors. Since technology development in these industries requires extensive development and use of computer programs, the Korean firms may have been able to accumulate relevant knowledge. This means the reform gave rise to absorptive capacity that allowed them to search for and seize new market opportunities. Hence, we hypothesize that the 1986 IPR Reform contributed to enhancing the innovation capability of Korean inventors in computer software related industries. This rational formulates our second hypothesis.

H2. The 1986 Korean IPR Reform was effective in improving the innovation capability of Korean inventors in computer software relevant industries.

5. DATA AND METHOD

5.1. Dataset

Of the various ways to evaluate the performance or innovation capability of inventors, we choose patents as the proxy for the outcome of an innovative effort. We start by collecting information about patents filed by Korean applicants from 1982 to 1991 in U.S., Germany, and United Kingdom (U.K)[1] from the Worldwide Patent Statistical. Database (PATSTAT) 2016. The aforementioned period is selected so that we can include patents filed before and after the 1986 IPR Reform.

Not all applicants living in Korea have Korean nationality. For instance, foreign companies operating in Korea are coded as residents of Korea in the PATSTAT, and they can be included in our sample even if all the inventors reside outside Korea. To discard such cases, we exclude patent applications with no Korea-resident inventors. We drop patents that have no valid incomplete information and only keep utility patents. These data screening process leaves us with 3,136 patent applications. We then identify pharmaceutical and computer software patents among them.

We start by grouping patents into pharmaceutical, computer software related patents, and control group by using the Nomenclature of Economic Activities (NACE) codes assigned to each patent. The NACE code scheme provides a unique category of pharmaceutical products called “manufacture of basic pharmaceutical products and pharmaceutical preparations” (hereafter, Pharma-NACE). Yet, some of the patents that are not included in this category could possibly be related to the pharmaceutical technology. To systematically capture pharmaceutical patents outside the category of Pharma-NACE, we select the top 3 NACE codes that are frequently co-assigned with Pharma-NACE. The two additional NACE codes obtained from this process are: “manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms” and “manufacture of medical and dental instruments and supplies.” We check whether the rest of the two NACE codes are also in the three most co-occurred NACE codes for one another. If a NACE code of the three is not in the top 3 for one another in terms of the co-occurrence frequency, we drop it from the list of NACE codes for pharmaceutical patents. This screening process leaves us with “manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms” and “manufacture of basic pharmaceutical products and pharmaceutical preparations” as NACE codes related to pharmaceuticals. After defining pharmaceutical patents with these two NACE codes, we are left with 330 of them.

In contrast to pharmaceutical patents, the NACE scheme does not provide a unique category for computer software (and patents in the PATSTAT). To capture computer software patents systematically, we start by searching for a set of patents whose abstract fields include the word “software.” The search result gives us 13 patents. Next, we profile their NACE codes and select the top 3 NACE codes in terms of frequency. These codes are “manufacture of communication equipment,” “manufacture of office machinery and equipment (except computers and peripheral equipment),” and “manufacture of computers and peripheral equipment.” We check whether each NACE code in the top 3 co-occurred with the other two in the sample. If not, the NACE code in question is dropped

[1] In the 1980s, U.S., U.K., and Germany were the top 3 foreign patent offices to which Korean inventors filed their patents applications.

from the list. This test does not drop any of the three candidates for the NACE codes of computer software patents. Our effort to identify software patents yields 1,174 results.

We adopt a strict process to construct control group patents. We profile all the NACE codes assigned to the collected computer software and the pharmaceutical patents. Then, we identify the NACE codes that do not appeare in the NACE code profile of computer software nor pharmaceutical patents. Finally, we select patents that are assigned to at least one of the NACE codes in this list, which are unrelated (or weakly related to) to pharmaceutical and computer software patents (see Appendix). This process gives 414 patents in total.

5.2. Variables

Since our focus is on how a reform affects the quality of patented inventions rather than the number of patents, we employ indicators of patent quality as dependent variables. We initially focus on variable that indicate the technical significance of patented inventions. This is often measured by the patent forward citation index (Harhoff, Scherer, & Vopel, 2003; Lanjouw & Schankerman, 1999; Trajtenberg, 1990). The patent forward citation index refers to the number of citations received by a patent from subsequent patent applications. The higher the number of forward citations, the higher the patent's technological significance. Because older patents are likely to have received more citations that relatively recent ones, we only count citations received in the 5 years following the year of application.

The second dependent variable is the number of patent claims. The number of independent patent claim is an indicator of the legal scope of a patent (Marco, Sarnoff, & deGrazia, 2016) or the extent of inventive steps that the patent application encompasses (Reitzig, 2004). Hence, the number of patent claims can be used to illustrate how many technological features are protected by the patent. We use this indicator only for the U.S. patents in the sample because the information about the patent claim is available only for U.S. patents in PATSTAT.

For independent variables, we generate a set of dummy variables for software (*Software*) and pharmaceutical (*Pharma*) patents. For software patents, the Software variable takes 1, or 0 otherwise. Likewise, Pharma variable takes 1 for pharmaceutical patents, or 0 otherwise. The Software and Pharma variables for the control group patents are set to 0s. We additionally create a binary variable, post1986, that takes 1 if a patent in question was filed after 1986, or 0 otherwise. Next, we create interaction terms between the post1986 and software and pharma variables (i.e., *software*1986* and *pharma*1986* respectively) to accommodate a difference-in-difference approach.

We introduce two control variables into our regression model. The first control variable is an indicator of whether a patent application is jointly filed by multiple applicants. The likelihood of joint patent applications (*collaboration*), while associated with two indicators of patent quality indexes, is heterogeneous across different technological sectors. To control for the potential confounding effect caused by joint patent applications, we create a binary variable that takes 1 for a patent with multiple applicants or 0 otherwise. The second variable is the total number of citations made by a patent (*backward citation*). The backward citation is used as an indicator of the breadth of prior arts to the patent of interest (Ziedonis, 2004). The higher the backward citation, the wider the breadth of prior arts. The number of prior arts of an invention can be systematically associated with the forward citation as well as the number of patent claims while increases with time along with the increasing number of patents applications. To control for the potential confounding effect caused by the breadth of prior arts, we introduce the backward citation as a control variable.

We run the negative binomial and Poisson regression models because the two dependent variables are also count-variables. The following formula depicts the econometric model.

$$Y^* = \beta_0 + \beta_1 X * post1986 + \beta_2 post1986 + \beta_3 pharma + \beta_4 software + \sum_j \alpha_j C_j + \epsilon$$

Where Y^* is a latent variable of the dependent variable of interest, x: a dummy variable for software or pharmaceutical patents, *post1986*: a binary variable that takes 1 for patents filed after 1986, *software*: a dummy variable for computer software patents, *pharma*: a binary variable for pharmaceutical patents, C: a set of control variables, control group = reference group, and ϵ is an error term. The first hypothesis expects β_1 that is not far from 0 and the second hypothesis expects the positively significant β_1.

6. RESULTS

6.1. Descriptive Statistics

Table 2 summarizes the descriptive statistics of the key variables across different technological sectors. Our dataset contains 330 pharmaceutical patents (17.2%), 1,174 software patents (61.2%), and 414 control group patents (21.6%).

TABLE 2. Descriptive Statistics by Group

Pharmaceutical Patents (N=330)						
Variable	Obs	Median	Mean	Std. Dev.	Min	Max
Forward Citation	330	0	1.139394	1.958217	0	13
Number of Patent Claims*	210	7	8.1	6.475164	1	58
Post1986	330	1	0.8969697	0.3044601	0	1
Backward Citation	330	3	4.515152	5.525961	0	28
Collaboration	330	1	0.7727273	0.4197066	0	1

Computer Software Related Patents (N=1,174)						
Variable	Obs	Median	Mean	Std. Dev.	Min	Max
Forward Citation	1174	1	2.26661	3.166528	0	29

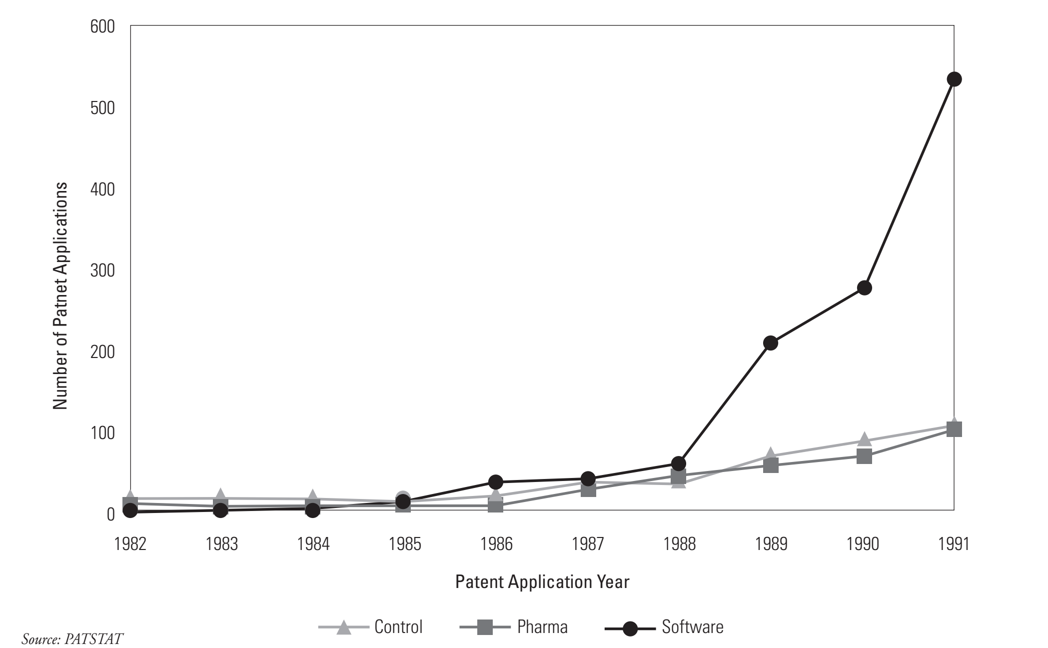
Number of Patent Claims*	842	7	9.893112	9.485854	1	128
Post1986	1174	1	0.9505963	0.2168019	0	1
Backward Citation	1174	4	4.991482	4.09311	0	27
Collaboration	1174	0	0.2035775	0.4028299	0	1

Control Group Patents (N=414)						
Variable	Obs	Median	Mean	Std. Dev.	Min	Max
Forward Citation	414	1	1.673913	2.332515	0	16
Number of Patent Claims*	336	6	7.363095	5.965498	1	41
Post1986	414	1	0.8067633	0.3953148	0	1
Backward Citation	414	6	6.442029	4.807709	0	35
Collaboration	414	0	0.2318841	0.422546	0	1

** US patents only*

Among the 330 pharmaceutical patents, 296 (89.7%) were filed after 1986, while 1,116 of the 1,174 software patents (95.1%) were filed after the 1986 IPR Reform. This implies that there was a rapid increase in the number of patents filed for pharmaceutical and computer software inventions by Korean applicants after the reform. However, this does not imply that the reform caused the rapid increase in the number of patent applications in the two sectors because it could simply be a result of the explosive growth of the Korean economy in the late 1980s. Figure 1 details the number of patents filed by Korean applicants in each group.

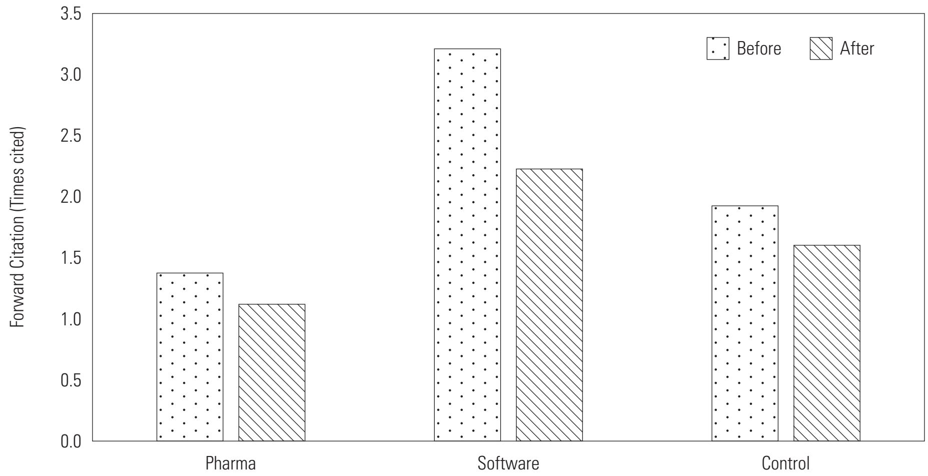
FIGURE 1. Number of Patent Applications by Year



Source: PATSTAT

Figure 2 compares the mean values of the two patent quality indicators for patents filed before and after the reform. The forward citation index seems to decrease after the reform for all three groups.

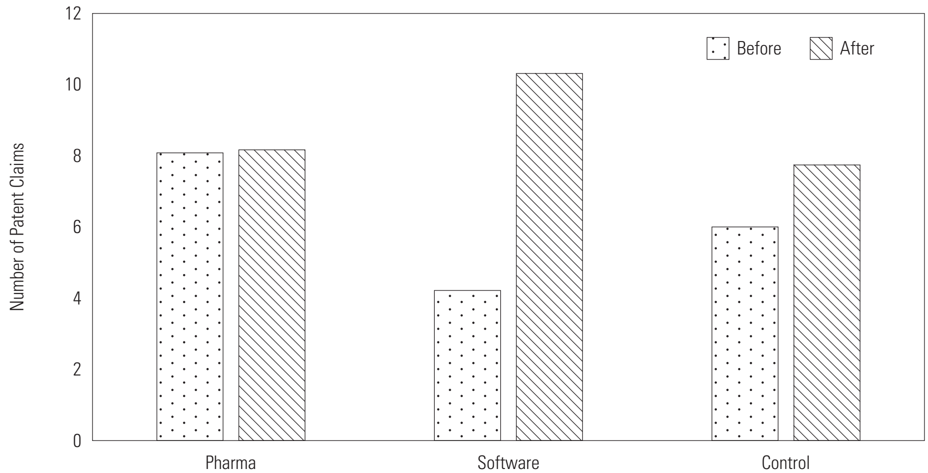
FIGURE 2. Comparison of Forward Citation Index by Group



Source: PATSTAT

For the number of patent claims, we only analyze the number of independent claims for U.S. patents. Figure 3 compares the average number of patent claims in the three groups. For pharmaceutical patents, the number of claims does not change significantly after the reform, while both the software and control group patents see an increase.

FIGURE 3. Comparison of the Number of Patent Claims by Group



Source: PATSTAT

6.2. Regression Analysis

Table 3 shows regression results. Since the standard deviations of the forward citation index and the number of patent claims variables are larger than their mean values, they are subject to the problem of overdispersion. To take this into account, we run the negative binomial regression model. To test robustness, we run the Poisson models with the same specifications (See Appendix).

The first column reports the regression results of the pharmaceutical and control groups patents, while the second column reports the regression results of the software and control group patents. In both cases, the coefficient of *post1986* is statistically insignificant at a significance level of 0.05 (-0.154 and -0.163 respectively). This indicates that for the control group patents, there is no notable difference in the forward citation index between the patents filed before the reform and those filed after. Moreover, this implies that the change in the average technical significance of the control group appears to be unaffected by the reform. The coefficients of both *Pharma*1986 (-0.135)* in the first column and *software*1986 (-0.245)* in the second column are statistically insignificant at a significance level of 0.05. These results indicate that there is no notable change in the technical significance of software and pharmaceutical patents after the reform, as compared to that of the control group patents. The hypothesis 1 is supported whereas the hypothesis 2 is not.

TABLE 3. Main Regression Results

	Forward Citation			Number of Independent Claims		
VARIABLES	H1	H2	H1&H2	H1	H2	H1&H2
Pharma*post1986	-0.135 (0.300)		-0.138 (0.299)	-0.281 (0.156)		-0.288 (0.157)
Software*post1986		-0.245 (0.212)	-0.250 (0.213)		**0.655***** **(0.164)**	**0.656***** **(0.164)**
Pharma	-0.254 (0.275)		-0.324 (0.274)	0.272 (0.139)		0.304* (0.139)
Software		0.655*** (0.194)	0.667*** (0.194)		-0.320* (0.154)	-0.324* (0.154)
Post1986	-0.154 (0.168)	-0.163 (0.171)	-0.160 (0.171)	0.223* (0.095)	0.215* (0.096)	0.217* (0.095)
Collaboration	0.129 (0.125)	0.301*** (0.086)	0.267*** (0.080)	0.138* (0.070)	0.088 (0.061)	0.103 (0.055)
Backward Citation	0.078*** (0.011)	0.074*** (0.008)	0.081*** (0.007)	0.022*** (0.007)	0.031*** (0.007)	0.029*** (0.006)
Constant	0.064 (0.171)	0.061 (0.165)	0.021 (0.163)	1.612*** (0.095)	1.562*** (0.095)	1.576*** (0.092)
lnalpha	0.247* (0.097)	0.266*** (0.059)	0.291*** (0.055)	-1.001*** (0.089)	-0.686*** (0.048)	-0.730*** (0.046)
US Patents only	No	No	No	Yes	Yes	Yes
Sample	Excl. software	Excl. Pharma	All	Excl. software	Excl. Pharma	All
Observations	744	1,588	1,918	546	1,178	1,388
Pseudo R2	0.0280	0.0178	0.0265	0.00830	0.0162	0.0153

*Robust standard errors in parentheses, *** p<0.001, ** p<0.01, * p<0.05*
Negative Binomial regression model
DVs: 5-year forward citation and number of independent claims
Information about the number of patent claims is available for U.S. patents only

The third column reports the regression results of *pharma*post1986* and *software*post1986* together with the entire sample. This shows consistent findings with the two prior regressions. The fourth to sixth columns report the regression results of the number of patent claims. The coefficients of *post1986* in both models are positively significant at a significance level of 0.05 (0.223 and 0.215 respectively). This indicates that on average the number of technological features that a patent protects increases after the reform for the control group patents. The coefficient of *pharma*post1986* in the fourth column is statistically insignificant at a significance level of 0.05, while the coefficient of *software*post1986* in the fifth column is positively significant at 0.01 (0.655). These results indicate that the reform does not affect the number of inventive steps that a pharmaceutical patent contains, as compared to a control group patent. This supports the hypothesis 1. In contrast, software patents after the reform contain more inventive steps than those filed before the reform, as compared to the control group patents. This result supports the hypothesis 2. In summary, the number of inventive steps that a software patent claims increases more extensively compared to both the control group and pharmaceutical patents. The regression results of *pharma*post1986* and *software*post1986* along with the entire sample give consistent findings.

Next, we run another set of regressions to directly compare the degree of change in the two patent quality indicators between pharmaceutical and software patents. For this analysis, we exclude the control group patents and set the software patents as the reference group. Table 4 reports the results.

TABLE 4. Pharmaceutical vs. Software Patents

VARIABLES	Forward Citation	Number of Claims
Pharma*post1986	0.115 (0.277)	-0.946*** (0.184)
Pharma	-1.010*** (0.259)	0.632*** (0.173)
Post1986	-0.416** (0.128)	0.872*** (0.134)
Collaboration	0.292** (0.093)	0.098 (0.066)
Backward Citation	0.089*** (0.009)	0.030*** (0.007)
Constant	0.647*** (0.129)	1.244*** (0.137)
lnalpha	0.333*** (0.062)	-0.668*** (0.052)
Observations	1,504	1,052
Pseudo R2	0.0294	0.0134

The first column reports the regression results with the forward citation index as a dependent variable. The second column reports the result with the number of patent claims as a dependent variable. The statistically insignificant coefficient of *pharma*post1986* (0.115) at a significance level of 0.05 indicates that the changes in the forward citation index after the reform for both pharmaceutical and software patents do not differ significantly. However, the second column shows a substantial difference between pharmaceutical and software patents in terms of the number of patent claims. The negatively significant coefficient of *pharma*post1986* (-0.946) at a significance level of 0.001 indicates that the change in the number of patent claims of pharmaceutical patents is significantly lower than that of software patents. The analysis of the series of regressions is summarized in Table 5.

TABLE 5. Summary of Hypotheses Test Results

Hypothesis	Technological Significance of Patented Invention	Number of Inventive Steps that a Patent Protects
H1	Supported	Supported
H2	Not supported	Supported

7. DISCUSSION

This study examines the impact of the 1986 IPR Reform in Korea on the innovation capability of Korean inventors in two industrial sectors – pharmaceuticals and computer software technology. We hypothesize that the IPR regime changed by the reform had no significant impact on the innovation capability of Korean inventors in the pharmaceutical sector, whereas the introduction of protection of computer software through copyrights improved the innovation capability of Korean inventors in the computer software sector. To test the two hypotheses, we employ a difference-in-difference approach for the patents produced by Korean inventors between 1982 and 1991.

We measure the innovation capability of Korean inventors using two patent quality indexes, which indicate the technical significance of a patented invention, and the extent of inventive steps that it claims. Our series of regressions gives several interesting findings, which suggest that the overall impact of the reform cannot be simply understood with respect to the improvement of innovation capability of Korean inventors.

Firstly, our analysis shows that the technical significance of a pharmaceutical invention does not change after the reform, as compared to the control group. Interestingly, the reform does not seem to influence the technical significance of computer software patents as compared to the control group patents too. Contrary to our hypothesis, these findings suggest that the impact of the 1986 IPR Reform on the technological innovation capability of Korean inventors in both sectors is marginal at most. There are many explanations for our findings. For instance, efforts to improve technological innovation capability through institutional incentives such as strengthening IPR are unlikely to be instantaneous. There might be a long delay incentives from new institutions and their impact on innovation capability can be realized. Inventors may take time to incorporate the benefits of new institutions in their innovation activities.[2] It could be argued that the 1986 IPR Reform was not effective in promoting innovations at all. For pharmaceutical innovations, the industrial competitiveness and absorptive capacity of the Korean pharmaceutical firms might not have been sufficient for them to benefit from the new institutions. After all, the Korean government had legitimate concerns about the “early” introduction of pharmaceutical patents. For the computer software inventions, incentivizing innovation by protecting copyrights might not have been as effective as protecting patents. This is because while patents protect the ideas or the algorithm of software inventions, copyrights only provide protection for the expression of inventions, thereby increasing the likelihood of being invented-around (Greenhalgh & Rogers, 2010). Therefore, the introduction of computer-program copyrights may not have provided sufficient incentives to enhance the quality of inventions.

Secondly, according to our analysis of the extent of inventive steps that a patent claims for legal protection (number of claims), the 1986 IPR Reform seems to increase the number of patent claims for computer software patents. However, we could not observe a significant change in legal scope of for pharmaceutical patents on average as compared to the control group patents. Allowing Korean inventors to protect their computer software inventions using copyrights in Korea may incentivize them to engage in innovation complemented by computer software inventions. The introduction of computer-program copyrights may provide “legal” complementarity between patents and copyrights as the expression of ideas (codes), because each patent claim can now be protected by copyrights. Accordingly, this institutional incentive may drive Korea inventors to add further claims in terms of new technological features which are enabled by computer software. Before the reform in 1986, adding a claim for a new technological feature complemented by computer software was not encouraged because a computer software invention could not be protected by any means. Accordingly, the marginal benefit of adding one more patent claim complemented by computer software is higher under a proper protection mechanism than in the absence of such an institutional device. Interestingly, we could not observe this effect for the pharmaceutical sector.

We argue that this difference can be explained firstly by the heterogeneous levels of absorptive capacity of Korean inventors in the two industrial sectors in the 1980s. There were only few Korean pharmaceutical firms in the 1980s and their industrial competitiveness was relatively weak. In contrast, there were several leading firms in the computer-software related industry including home appliances, semiconductor devices, or electronic devices. Examples include Goldstar (now known as LG), Samsung Electronics, and Hyundai Semiconductor. These firms have accumulated experience and expertise in R&D since the 1970s and emerged as key players in the global electronics market. Further, compared to other industries, firms in these two sectors put a great deal of effort into R&D and received much support from the Korean government through its direct industrial policies. For instance, many public research institutes of Korea such as the Electronic Telecommunication Re-

[2] A similar lag was observed when Japanese adopted the multiple-claim patent system in 1988 (Sakakibara & Branstetter, 2001).

search Institute (ETRI) or the Korean Institute of Science and Technology (KIST) were actively engaged in technology transfers to private firms in this industry. Thus, firms in the computer software related industry had greater accumulated knowledge which could be used to benefit from the new IPR reform in 1986.

The difference between the two industries in terms of findings can also be explained by the way inventions are protected by copyrights protects. The introduction of copyrights itself did not increase the technical quality of software patents. This is because copyrights do not provide a sufficient means of protection. Therefore, the absence of technical enhancement in the software industry may be unrelated to the lack of absorptive capacity as observed in the pharmaceutical industry. Meanwhile, the introduction of copyrights may have provided "legal" complementarity between patents and copyrights, results in a significant increase in the number of claims in the software industry. We argue that this "legal" complementarity is better exploited when firms have a good understanding of contextual knowledge. For the pharmaceutical industry, we do not observe the same dynamics.

These findings should be carefully interpreted because the increase in the number of patent claims could simply indicate the change of patenting behavior of inventors rather than an improvement in their innovation capabilities. Since a patent claim is constructed strategically and the scope of patent protection is determined based on the "claim," inventors have an incentive to construct as many patent claims as possible even when the technological value of their inventions is not particularly high. Given that the technological significance of patents in both sectors shows no significant change, we argue that the 1986 IPR Reform may have changed the patenting behavior of inventors in the computer software related industry rather than improving their innovation capabilities. To a certain extent, this claim supports the studies by Branstetter and Fisman (2006) and Zhao (2006) that demonstrate how a new IPR regime affects firms' IPR strategies instead of their innovation activities. Whether or not the change in the number of patent claims in the computer software related industry stems from this impact of the reform on the innovation activities of Korean innovators remains an open question.

In summary, we could not find evidence that the 1986 IPR Reform affected the technological innovation capability of Korean inventors in both pharmaceutical and computer software sectors. In contrast, the extent to which a patent includes inventive steps increased for software inventions, but not for pharmaceutical inventions. This could be explained by the difference between copyrights and patents as well as by the difference in the industrial absorptive capacity of firms in the two sectors and their changing approaches to patenting.

8. CONCLUSION

This research has investigated the varying impacts of the 1986 Korean IPR Reform on the quality of patented inventions with respect to heterogenous ex-ante absorptive capacities. Although pharmaceutical and computer software related industries differ in their respective levels of absorptive capacities, we found no significant technical improvement in their patented inventions post 1986. There are several explanations for this – various lags associated with the adoption of a new IPR regime, the low absorptive capacity of the pharmaceutical sector, and the difference between copyrights and patents as effective means of protecting inventions. Our results also showed a significant increase in the number of patent claims for computer software patents. We argue that industries with higher absorptive capacities could better capitalize on the benefits of a new IPR regime to protect inventions by allowing inventors to broaden the legal scope of their patents. Furthermore, the introduction of copyrights may have provided "legal" complementarity between patents and copyrights, which led to the significant increase in the number of claims for software patents. Any change in the IPR regime could affect firms' patenting behavior without changing their innovative capacities, which leads to the following academic and policy implications.

Firstly, most IPR literatures have shown that a strong IPR regime induces a greater level of innovation. IPR generally provide effective protection for inventions by reducing the uncertainties associated with their appropriabilities. Some suggest that a strong IPR can increase innovation incentives (Nordhaus, 1969). Yet, our results show no evidence. Rather, we partially observe evidence of change in firms' patenting behaviors. It is important to note firms' decision making dynamics that consider various marginal benefits with respect to a new IPR regime. These results are in parallel with previous literatures, which demonstrated the evidence of change in firms' IPR strategies in response to a IPR reform (Branstetter & Fisman, 2006; Zhao, 2006).

This research also provides an interesting implication for developing countries. Previous literatures give ample evidence with regards to adequate economic development levels for IPR to have positive impact on domestic innovations (Chen & Puttitanun, 2005; Kim, Lee, Park & Choo, 2016; Park & Ginarte, 1997). Subsequently, many policy suggestions revolved around supporting stronger IPR regime in catching-up countries once their industries and underlying infrastructure became "innovative" enough. Yet, the 1986 IPR Reform in Korea provides no evidence of improving the quality of inventions. Rather, the evidence shows a change in the patenting behaviors of inventors in the computer-software related industry. Our findings indicate that a strong IPR regime does not necessary increase innovation capacities but merely leads to change in the patenting behaviors of inventors, especially when target industries already have high absorptive capacities and patenting experiences.

We do, however, acknowledge the limitations of our research. Firstly, there may be different time-lagging effects involved in our two dependent variables. The previous section discusses how the potential presence of a time lag associated with a policy reform may explain the absence of significant relations between the technical quality of patents and the reform. Our observations have been drawn from patents files between 1982 and 1991, and the five years considered for calculating the forward citation index may not be sufficient to capture the long-term effects of a new IPR policy on the technical quality of patented inventions. On the other hand, it could be argued that an IPR reform may take much less time to influence the legal quality since it mostly involves identifying relevant complementary technologies. Yet, we would like to mention that the 10-year time span was implemented to avoid selecting patents that might have been affected by other IPR reforms. We also acknowledge that our research did not consider firm-specific factors. As one previous qualitative investigation shows (Sakakibara & Branstetter, 2001), such factors may influence the way firms cope with institutional changes related with IPR. The absence of firm-specific data may have foiled any possible observations of micro-dynamics between institutional changes and firms. We hope that these limitations are addressed by future research.

REFERENCES

Allred, B. B., & Park, G. W. (2007). Patent rights and innovative activity: Evidence from national and firm-level data. *Journal of International Business Studies, 38*(6), 878-900. doi:10.1057/palgrave.jibs.8400306

Arora, A., Fosfuri, A., & Gambardella, A. (2001). *Markets for technologies*. Cambridge: MIT Press.

Arora, A., & Merges, R. P. (2004). Specialized supply firms, property rights and firm boundaries. *Industrial and Corporate Change, 13*(3), 451-475. doi:10.1093/icc/dth018

Besley, T. (1995). Property rights and investment incentives: Theory and evidence from Ghana. *Journal of Political Economy, 103*(5), 903-937.

Branstetter, L. G., & Fisman, R. (2006). Do stronger intellectual property rights increase international technology transfer? Empirical evidence from US firm-level panel data. *The Quarterly Journal of Economics, 121*(1), 321-349.

Chen, Y., & Puttitanun, T. (2005). Intellectual property rights and innovation in developing countries. *Journal of Development Economics, 78*(2), 474-493. doi:http://dx.doi.org/10.1016/j.jdeveco.2004.11.005

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128-152.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2000). *Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not)* (NBER Working Paper Series 7552). Retrieved from http://www.nber.org/papers/w7552.pdf doi: 10.3386/w7552

Gallini, N. T. (1984). Deterrence by market sharing: A strategic incentive for licensing. *The American Economic Review, 74*(5), 931-941.

Gallini, N. T. (1992). Patent policy and costly imitation. *The RAND Journal of Economics, 23*(1), 52-63. doi: 10.2307/2555432

Gallini, N. T. (2002). The economics of patents: Lessons from recent U.S. patent reform. *The Journal of Economic Perspectives, 16*(2), 131-154.

Gallini, N. T., & Winter, R. A. (1985). Licensing in the theory of innovation. *The RAND Journal of Economics, 16*(2), 237-252. doi:10.2307/2555412

Ginarte, J. C., & Park, W. G. (1997). Determinants of patent rights: A cross-national study. *Research Policy, 26*(3), 283-301. doi:http://dx.doi.org/10.1016/S0048-7333(97)00022-X

Gould, D. M., & Gruben, W. C. (1996). The role of intellectual property rights in economic growth. *Journal of Development Economics, 48*(2), 323-350. doi:http://dx.doi.org/10.1016/0304-3878(95)00039-9

Greenhalgh, C., & Rogers, M. (2010). *Innovation, intellectual property, and economic growth*. New Jersey: Princeton University Press.

Hall, B. H., & Ziedonis, R. H. (2001). The patent paradox revisited: An empirical study of patenting in the U.S. semiconductor industry, 1979-1995. *The RAND Journal of Economics, 32*(1), 101-128.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy, 32*(8), 1343-1363.

Horowitz, A. W., & Edwin, L. C. L. (1996). Patent length and the rate of innovation. *International Economic Review, 37*(4), 785-801. doi:10.2307/2527311

Kanwar, S., & Evenson, R. (2003). Does intellectual property protection spur technological change? *Oxford Economic*

Papers, 55(2), 235-264. doi:10.1093/oep/55.2.235

Kim, G. (1984). *A study on the formulation of master plan for the promotion of information industry* (Trend/Research Report 200). Daejeon: KISTI. Available at http://www.ndsl.kr/ndsl/commons/util/ndslOriginalView.do

Kim, J. (1986, March 29). Business sentiments on the introduction of software copyrights. *Maeil Business Newspaper*.

Kim, Y. K., Lee, K., Park, W. G., & Choo, K. (2012). Appropriate intellectual property protection and economic growth in countries at different levels of development. *Research Policy, 41*(2), 358-375.

Korean Intellectual Property Office (KIPO). (2007). *30 years of challenge toward the strong Country of intellectual property*. Daejeon: KIPO.

Kortum, S., & Lerner, J. (1999). What is behind the recent surge in patenting? *Research Policy, 28*(1), 1-22. doi:http://dx.doi.org/10.1016/S0048-7333(98)00082-1

La Croix, S. J., & Kawaura, A. (1996). Product patent reform and its impact on Korea's pharmaceutical industry. *International Economic Journal, 10*(1), 109-124. doi:10.1080/10168739600000031

Lanjouw, J. O., & Schankerman, M. (1999). *The quality of ideas: measuring innovation with multiple indicators* (NBER Working Paper Series). Retrieved from http://www.nber.org/papers/w7345.pdf doi: 10.3386/w7345

Lo, S. (2011). Strengthening intellectual property rights: Experience from the 1986 Taiwanese patent reforms. *International Journal of Industrial Organization, 29*(5), 524-536.

Mancusi, M. L. (2008). International spillovers and absorptive capacity: A cross-country cross-sector analysis based on patents and citations. *Journal of International Economics, 76*(2), 155-165.

Marco, A. C., Sarnoff, J. D., & deGrazia, C. (2016). *Patent claims and patent scope* (USPTO Economic Working Paper 2016-04). Hoover Institution Working Group on Intellectual Property, Innovation, and Prosperity Stanford University Available at SSRN: https://ssrn.com/abstract=2825317 or http://dx.doi.org/10.2139/ssrn.2825317

Reasons to delay introduction of pharmaceutical patents before enhancing domestic research capacity Editorial. (1984, March 31). *Maeil Business Newspaper* (MBN).

Moser, P. (2003). *How do patent laws influence innovation? Evidence from nineteenth-century world fairs*. The American Economic Review, *95*(4), 1214-1236.

Nordhaus, W. D. (1969). *Invention, growth and welfare: A theoretical treatment of technological change*. Cambridge: MIT Press.

North, D. C. (1986). The new institutional economics. *Journal of Institutional and Theoretical Economics (JITE) / Zeitschrift die gesamte Staatswissenschaft, 142*(1), 230-237.

O'Donoghue, T., Scotchmer, S., & Thisse, J.-F. (1998). Patent breadth, patent life, and the pace of technological progress. *Journal of Economics & Management Strategy, 7*(1), 1-32. doi:10.1111/j.1430-9134.1998.00001.x

Park, W. G., & Ginarte, J. C. (1997). Intellectual property rights and economic growth. *Contemporary Economic Policy, 15*(3), 51-61. doi:10.1111/j.1465-7287.1997.tb00477.x

Qian, Y. (2008). Impacts of entry by counterfeiters. *The Quarterly Journal of Economics, 123*(4), 1577-1609.

Reitzig, M. (2004). Improving patent valuations for management purposes—validating new indicators by analyzing application rationales. *Research Policy, 33*(6), 939-957.

Sakakibara, M., & Branstetter, L. (2001). Do stronger patents induce more innovation? Evidence from the 1988 Japanese patent law reforms. *RAND Journal of Economics, 32*(1), 77-100.

Shapiro, C. (2001). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. *Innovation Policy and the Economy, Volume 1* (pp. 119-150). Cambridge: MIT press. Retrieved from http://www.nber.org/chapters/c10778.pdf

Song, J. (2006). Intellectual property regimes, innovative capabilities, and patenting in Korea. *Seoul Journal of Business, 12*(2), 57-75.

Stiglitz, J. E. (1989). Markets, market failures, and development. *The American Economic Review, 79*(2), 197-203.

Trajtenberg, M. (1990). A penny for your quotes: patent citations and the value of innovations. *The Rand Journal of Economics, 21*(1), 172-187.

Williamson, O. E. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature, 38*(3), 595-613.

Woo, S., Jang, P., & Kim, Y. (2015). Effects of intellectual property rights and patented knowledge in innovation and industry value added: A multinational empirical analysis of different industries. *Technovation, 43-44*, 49-63.

Zhao, M. (2006). Conducting R&D in countries with weak intellectual property rights protection. *Management Science, 52*(8), 1185-1199.

Ziedonis, R. H. (2004). Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. *Management Science, 50*(6), 804-820.

APPENDIX

TABLE AP1. Selected NACE Code for Control Group Patents

Manufacture of motor vehicles
Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks
Manufacture of metal forming machinery and machine tools
Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
Manufacture of non-domestic cooling and ventilation equipment
Specialised construction activities
Manufacture of other transport equipment
Manufacture of cement, lime and plaster
Manufacture of furniture
Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
Manufacture of glass and glass products
Manufacture of machinery for textile, apparel and leather production
Manufacture of lifting and handling equipment
Manufacture of leather and related products
Manufacture of watches and clocks
Manufacture of textiles
Construction of utility projects
Manufacture of parts and accessories for motor vehicles
Manufacture of wearing apparel
Manufacture of ceramic sanitary fixtures
Manufacture of fasteners and screw machine products
Manufacture of paper and paper products
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Construction of water projects
Manufacture of machinery for mining, quarrying and construction
Manufacture of other taps and valves
Manufacture of ovens, furnaces and furnace burners

TABLE AP2. Main Regression Results with Poisson model

VARIABLES	Forward Citation			Number of Independent Claims		
	H1	H2	H1&H2	H1	H2	H1&H2
Pharma*post1986	-0.087 (0.302)		-0.096 (0.301)	-0.301 (0.156)		-0.311* (0.158)
Software*post1986		-0.186 (0.209)	-0.185 (0.209)		0.620*** (0.164)	0.621*** (0.164)
Pharma	-0.279 (0.275)		-0.335 (0.276)	0.286* (0.136)		0.319* (0.137)
Software		0.608** (0.190)	0.612** (0.190)		-0.280 (0.155)	-0.287 (0.155)
Post1986	-0.204 (0.172)	-0.209 (0.172)	-0.210 (0.172)	0.239* (0.094)	0.232* (0.095)	0.235* (0.095)
Collaboration	0.159 (0.128)	0.300*** (0.084)	0.281*** (0.080)	0.137 (0.070)	0.088 (0.069)	0.098 (0.062)
Backward Citation	0.059*** (0.008)	0.056*** (0.006)	0.060*** (0.005)	0.023** (0.007)	0.034*** (0.008)	0.030*** (0.007)
Constant	0.215 (0.167)	0.200 (0.160)	0.178 (0.160)	1.593*** (0.099)	1.524*** (0.109)	1.549*** (0.101)
US Patents only	No	No	No	Yes	Yes	Yes
Sample	Excl. software	Excl. Pharma	All	Excl. software	Excl. Pharma	All
Observations	744	1,588	1,918	546	1,178	1,388
Pseudo R2	0.0581	0.0486	0.0674	0.0264	0.0603	0.0553

*Robust standard errors in parentheses, *** p<0.001, ** p<0.01, * p<0.05*
Negative Binomial regression model
DVs: 5-year forward citation and number of independent claims
Information about the number of patent claims is available for U.S. patents only