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Role of Intellectual Property Rights and Patent Propensity in R&D and Industry Value-added

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Abstract

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This thesis studies the relationship between intellectual property rights (IPR) and innovation and economic growth using 12 countries and four industries for the period of 1987-2005. The research also relies on the concept of patent propensity, which is represented by the ratio of patent stocks to R&D stocks. These patent propensities in the corresponding industries are used to explain the impact of this factor on the role IPR on R&D investments.

The empirical results using 3SLS estimation on simultaneous equations (R&D equation and value-added equations) revealed that the higher the patent propensity, the greater the contribution of IPR on R&D activities, suggesting that the prior innovative capacity is crucial for the effective establishment of an incentive mechanism of intellectual property rights. This research also shows that IPR in general is a good mechanism for allowing a virtuous cycle of R&D and value-added factors. The contribution of IPR, which appears in R&D activities, adds to the stock of R&D and therefore contributes to the value of the industry, meaning that IPR indirectly enhances economic growth by allowing the accumulation of a stock of knowledge. At the same time, the empirical results of the IPR's direct contribution on the value of industry suggest the possible presence of technology commercialization and licensing activities.

The sectoral comparison between four industries reveals several important characteristics. First, the concept of IPR itself is not related to R&D investments in electronic industries; given the presence of the ongoing debate on whether our IPR regime is providing the optimal environment for innovation (especially for the electronic industry), this empirical result can cause us to rethink our current patent system. Overall, the empirical results showed that the chemical and machine industries make significant IPR contributions via R&D investments. Regarding the role of IPR in the area of value-added industry, IPR was shown to be an effective mechanism in all industries except for the transportation equipment industry. The electronic industry by far showed the greatest direct effect of IPR, which can be explained by the vigorous technology commercialization and licensing activities in that industry.

Keywords: Intellectual Property Rights, Patent Propensity, R&D Investments, Industry value-added, Sequential Innovation, Technology Commercialization

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Contents

List of Tables

List of Figures

Chapter 1. Introduction

Technological change at present is without a doubt the most essential driver for long-term economic growth. As Romer (1990) has pointed out, endogenous technological changes have been key driver of economic growth in western countries. Therefore, the importance of technological capabilities has been a main policy agenda item for many developing countries. For example, developing countries of the past used strenuous industrial policies to promote domestic industrial and technological capabilities. As Smith (1991) argues, developing countries that have determinedly implemented a systematic, long-term strategy of raising their technological capabilities and skill levels by moving into more and more advanced product lines have done better than those which have not implemented policies to advance from low-skilled, labor-intensive assembly operations. However, with the emergence of the free trade doctrine and the WTO regime, the past form of direct innovation policy became vulnerable from international criticisms and pressure, mainly from developed countries (Bora, Lloyd, & Pengestu, 2000).

At the same time, the Trade-Related Aspects of Intellectual Property agreement (TRIPs) that was incorporated into the charter of the WTO in 1994 essentially created uniformity as regards patent standards throughout the membership of the WTO (Hall, 2007). Unlike direct industrial policy, IPR regimes seek to promote technological innovation by providing economic incentives for innovators. Because technological change arises in large part due to intentional actions taken by people who respond to market incentives, (Romer, 1990) the IPR regimes seem to provide innovation-friendly institutions without excessive interference from the government.

This leads to the question of whether our world became more innovative after the global strengthening and standardization of the intellectual property rights regime, After the rise of the IPR-friendly patent system and the emergence of the IT revolution, we witnessed enormous increases in patenting during the late 1990s (Kortum & Lerner, 1999). However, as J. Acs and Audretsch (1989) pointed out, patents alone cannot be a good measure of innovation, as not all patented inventions prove to be innovations and because many innovations are never patented.

At the same time, the IPR-friendly patent system has changed the characteristics of technological commercialization. The role of IPR, traditionally being an incentive mechanism that ensures an innovator's individual commercialization, now allows for increased licensing activities (Motohashi, 2008). Besides the increased commercialization activities under the strengthened IPR, many critics have attacked the current IPR regime in that such institutions can hinder sequential innovation. James Bessen and Maskin (2009) have argued that our current IPR regime discourages future innovators, resulting in limited amounts of innovation and welfare.

The paper will focus on the following issues. It attempts empirically to analyze the effects of IPR (Intellectual Property Rights) on different industries in terms of its effects on R&D investment and value-added industry. The first issues are the direct and indirect effects of IPR on different industries.

Because IPR promotes R&D and R&D promotes economic growth, a simultaneous equation model will be implemented to analyze virtuous cycles of ‘IPR-R&D-economic growth’. The next issue deals with the concept of patent propensity and its contribution to IPR’s role in R&D investments.

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Chapter2. IPR and Economic Growth

2.1 Traditional arguments on IPR

The traditional economic literature acknowledges IPR as an effective measure for spurring economic growth by providing incentives for innovation. The patent system allows an innovator temporary monopoly rights on inventions, thereby ensuring that the innovator recovers its innovation costs.

The cornerstone of the traditional economic argument in favor of patent protection is the 'open' characteristic of knowledge, which means that once an invention is known, everyone can use it with no additional R&D costs (Encaoua, Guellec, & Martínez, 2006). Because knowledge by nature is thought to have open and non-excludable characteristics, the open nature of knowledge means that the amount of knowledge does not decrease when used by others. More specifically, its consumption does not require any additional resources other than those devoted to its initial production, and once it is produced it can be subsequently used by others without its value being reduced (Encaoua et al., 2006). Knowledge also carries non-excludable characteristics, meaning that inventors cannot stop others from profiting from the commercialization of the invention. Therefore, knowledge is thought to be a public good, meaning that it will face problems of limited production and possibly result in market failure. Therefore, providing a strong IPR regime to ensure that innovators recover their innovations costs would, given this logic, encourage innovative activities.

2.2 Conventional arguments on IPR

2.22 Models supporting stronger IPR

Nordhaus (1969) predicts in the case of single and isolated inventions that a strong patent system will induce more investment in R&D. While this model is a useful starting point, it does not accurately depict many innovation processes, particularly those related to high technology sectors which experience rapid technological change. In addition, modern models of innovation expand from this framework by recognizing that innovation is a cumulative process (Nancy T. Gallini, 2002).

Merges and Nelson argued that the economic significance of a patent depends on its scope. One of their models viewed innovation as “cumulative,” meaning that it generates a continuum of improvements on some pioneering invention. For example, in industries such as those producing automobiles, aircraft, electric light systems, semiconductors and computers, technical advances are cumulative in the sense that today’s advances builds on and interact with many other features of existing technology (Merges & Nelson, 1990). They argue that given the probability of an inventor facing an infringement lawsuit from a previous patent holder, the benefits of a patent holder having stronger legal rights than a subsequent inventor are offset by the costs. In other words, while the current patent holder attempts to “hold up” the future innovation of a rival under a stronger IPR scope, they will also find themselves in a position of being held up by previous patent holders. Therefore, in this setting, the link between patent strength and innovation incentives is ambiguous (Nancy T. Gallini, 2002).

To what extent does the patent life induce optimal innovation? Nancy T. Gallini (2002) again argues that extending the patent period increases the incentive for imitation instead of R&D by an entrant. She argues that under a certain threshold of patent protection, increasing the patent length leads rivals to seek to imitate the patent because the longer the patent life, the longer rivals must wait to use the technology (N.T. Gallini, 1992). The empirical evidence shows that the length of the patent life and innovation exhibit an “inverted-U” shape, (Horowitz & Lai, 1996) meaning that the rate of innovation declines with increases in the patent life. This “inverted-U” shaped interpretation of strong IPR and innovation also appears in the work of Lerner (2000). From an international analysis of the relationship between patent strength and innovation, Lerner (2000) argued that strengthening patents has a positive effect on innovation if protection is initially low and a negative impact if patent protection is initially high. He argued that such a negative relationship can be attributed to the muted incentives of innovation given the nature of sequential development of technology. An interesting aspect of intellectual property rights is sequential innovation. J. Bessen and Maskin (2006) argue that when innovation is sequential in the sense that an invention directly follows a previous one, the exclusive rights provided by patents may impede access to the knowledge embedded in previous inventions and slow down technological progress (Encaoua et al., 2006).

2.3 Empirical Evidences

Many empirical studies show an ambiguous role of IPR on economic growth. The empirical analysis of Gould and Gruben (1996) shows that IPR institutions acts as an important driving factor in economic growth. Using the Rapp and Rozek index with panel data from 79 countries from 1960 to 1989, they showed that a strong IPR regime was in fact a significant factor in long-term economic growth. At the same time, they showed that stronger IPR had a more significant impact on economic growth in countries in which a more open trade regime existed. They argued that in closed markets, exogenous technological shocks are more important in determining economic growth than IPR because agents in closed markets are unlikely to innovate much themselves, perhaps preferring to spend their resources on legislative schemes to preserve their market shares (Gould & Gruben, 1996). Similarly, Kanwar and Evenson (2003) showed that strong IPR, even for developing countries, were a significant factor in driving R&D investment (innovation). Also, they found no evidence of an “inverted-U” shaped relationship between IPR and R&D investments. This empirical result suggests that developing countries should join TRIPS and that such an action will eventually yield long-term economic growth.

More reliable empirical works on IPR proxy measures were done by Walter G. Park and Ginarte (1997). They devised an IPR scoring method based on the following five categories: coverage, membership in international patent agreements, provisions for the loss of protection, enforcement mechanisms, and finally the duration of patents. With the endogenous economic growth model developed by Mankiw, Romer, and Weil (1992), their analysis shows that strong IPR significantly affected economic growth only for developed countries. This suggests, for developing countries, that R&D be directed towards different incentives (such as cultural rewards) or that a significant part of their R&D should be imitation (Walter G. Park & Ginarte, 1997)

Meanwhile, empirical evidence from Jaffe (2000), Hall and Ziedonis (2001) and Sakakibara and Branstetter (1999) show no relationship between enhanced IPR and R&D investments. Using 20 years of US R&D data from the 1980s, Jaffe (2000) found no evidence of IPR reform promoting R&D activities. Specifically, he showed that the R&D activities in the US started to increase before an era of US patent reform. Thus, he argues that patent reform cannot explain the surge in R&D activity.

Based on a Carnegie Mellon survey presented by Cohen (2000), which argued that “R&D managers in the semiconductor industry, consistently reporting patents as among least effective mechanisms for appropriating returns to R&D investment,” Hall and Ziedonis (2001) attempted to solve this paradox between rising patentability in the semiconductor industry and the survey. They explored this apparent paradox by conducting interviews with industry representatives and analyzing the patenting behavior of 95 US semiconductor firms from 1975 to 1999. The results suggested that the strengthening of US patent rights in the 1980s spawned “patent portfolio races” among capital-intensive firms, possibly yielding economic inefficiency. Also, they found that patent reforms in the US were significant in providing R&D incentives only for small and medium-sized enterprises.

Sakakibara and Branstetter (1999) also showed that the 1988 Japanese patent reforms had no significant effects on R&D spending. Despite interviews with practitioners suggesting that these reforms significantly expanded the scope of patent rights in Japan, the average response in terms of additional R&D effort and innovative output was quite modest.

2.4 Role of IPR in different Industries

As mentioned above, Cohen (2000) research with a Carnegie Mellon survey showed the different effects of IPR on different industries. Among firms’ appropriation methods, such as trade secrecy, lead time manipulations, and patents, the survey showed that patents were not in fact an effective means of appropriation. Moreover, appropriation dependency on patents differed among industries and whether or not the technology was in form of process innovation or product innovation. In the chemical and semiconductor industries, secrecy was the most effective means of appropriation, while for the communication, computer, steel and transportation industries, the technology lead-time advantage was the most effective measure of appropriation. Regarding the use of a patent as an appropriation measure, the pharmaceutical industry was the most patent-dependent industry. Allred and

Park (2007) empirical evidence also showed different effects of IPR on different industries. By analyzing data from 706 firms in 10 different industries, they argued that the IPR impact appears greatest in the scientific instrument and industrial chemical industries, while industries characterized by high fixed costs, long lead times, and other natural barriers (such as food and household appliances) were found to be less dependent on patents.

2.5 IPR and Technological Commercialization Activities.

Another phenomenon from strong IPR during the last two decades is the increased use of intangible assets such as patents in licensing and commercialization activities. Traditionally, the role of IPR centered on its function as an incentive mechanism. However, many recent studies have started to place emphasis on the ability of IPR to provide an environment for technological commercialization. Lichtenthaler (2008) argued that besides applying technological knowledge to products and services, firms may externally leverage their technology assets and technology licensing. Arora and Fosfuri (2003) argue that recent technological commercialization activities challenge the traditional wisdom that holds that an innovator can best profit from his innovation by commercializing it himself. From this perspective, licensing its intellectual properties is not an optimal choice, owing to the disclosure of knowledge, the transactions costs and the possible increase in competition, all of which can contribute to rent dissipation. However, under a competitive market for technology, Arora and Fosfuri

(2003) argue that innovative and incumbent firm may find licensing privately profitable. The technology commercialization aspects of IPR shed new lights on the role of intellectual property rights regarding the management of intangible assets such as knowledge by economic agents.

Chapter3. Research Frameworks

3.1 Basic Model

From the extensive literature review, it is not too difficult to realize such a complex and ambiguous role of IPR in the area of innovation. In general, literature with macroeconomic data such as economic growth (Gould & Gruben, 1996; Kanwar & Evenson, 2003; Walter G. Park & Ginarte, 1997) tends to supports stronger IPR, while firm-level analyses of the role of IPR in innovation (Hall & Ziedonis, 2001; Sakakibara & Branstetter, 1999) tend to find no significant relationship between strong IPR and innovation. However, an examination of the interrelationships between 'patent stock of knowledge,' IPR, and innovation has not been done. Patent stock of knowledge represents the level of available knowledge that is patented. If we apply this concept to a particular industry, the level of patented knowledge then becomes the patent propensity in that industry. This leads to the question of how patent propensity influences the role of IPR on innovation or vice versa. A positive influence on innovation suggests that a high level of patent propensity actually contributes to the positive role of IPR on enhancing innovation. On the other hand, a negative influence suggests quite a different story. When high patent propensity actually helps IPR to hinder innovation, the situation may show evidence of too much patenting activity, which hinders sequential innovation.

As presented above, this research focuses on the role of IPR and patent propensity in the areas of innovation and economic growth. Unlike previous work, this research involves an industry-level analysis. Thus far, in the IPR literature, panel methods which include both industry and country variables have not been used. This study will also take into account the dynamic effect of IPR on long-term economic growth (value-added industry). Therefore, the IPR effects channel is distinguished as a direct and an indirect channel. Figure 1 shows the basic framework of this research.

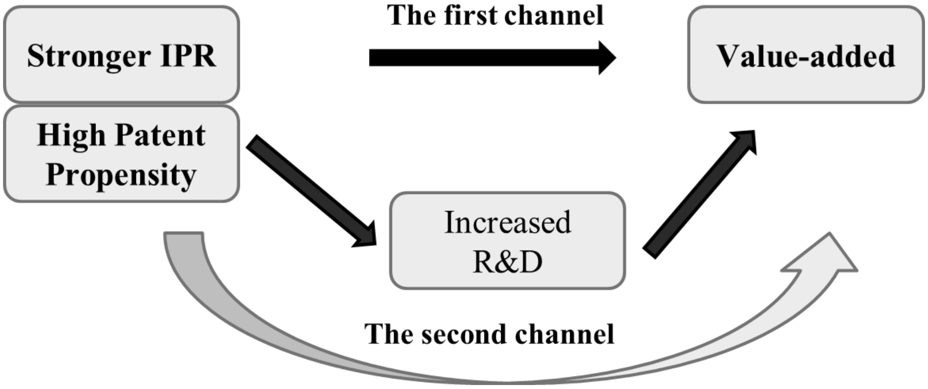


Figure 1. Direct Effect (first channel) and Indirect Effect (second channel)

3.1 Direct Effect

In the direct effect model, the focus was on the role of IPR in value-added industries. Therefore, the IPR index was created with a standard production function, where

(a) $VA_{ijt} = f(K_{ijt}, L_{ijt}, RDS_{ijt}, IPR_{jt},)$

The model resembles that of Mankiw et al. (1992), using knowledge stock as an input. Unlike Walter G. Park and Ginarte (1997), this model included an IPR index as a direct input factor, as this research does not seek to predict the contribution of IPR to general “economic growth.”

The classical literature suggests that IPR cause R&D growth, which then stimulates economic growth over the long term. This logic was also empirically analyzed in the works of Walter G. Park and Ginarte (1997). Kanwar and Evenson (2003) however did not consider the effect of IPR on the economy, as the effect of IPR protection on economic growth involves, first, the effect of protection on innovation and secondly the effect of innovation on economic growth. However, our model attempted to explore the direct effect of IPR protection on value-added industries as well as its role on R&D investment. As mentioned earlier, by looking at this direct effect, we try to interpret the role of IPR on value-added industry as economic activities lead by technological commercialization.

3.2 Indirect Effect

The indirect effect model focuses on the factors that contribute to R&D investment. In addition to value-added factors being the main control variables, the model includes IPR, patent propensity, and an interaction term between IPR and patent propensity. Therefore, a simultaneous equation encompassing (a) and (b) will be able provide us a more accurate explanation of the role of IPR on value-added industries in a dynamic setting.

(b) $$RDI_{ijt} = f(VA_{ijt}, IPR_{jt}, SQ_{ijt}, IPR_{jt} * SQ_{it})$$

Chapter4. Data and Methodology

4.1 R&D stock model

In our model, we explain IPR as an important factor explaining R&D investment. R&D investment therefore accumulates knowledge stock (R&D stocks), becoming one of the main factors attributing to the value-added function. Therefore, we calculated R&D stocks for different industries in each country using R&D investment data.

The most commonly employed approach in stock measurement is the perpetual inventory method (henceforth PIM) (Meinen, 1998). In PIM, R&D stock (RDS) is defined as the weighted sum of past investments with the weights given by the relative efficiency of R&D capital goods at different ages according to the following equation:

(a) $RDS_t = (RDS_{t-1} - D_t) + RDI_t$, where

RDS_t = R&D stock in year t

RDS_{t-1} = R&D stock in year t-1

D_t = Obsolescence index of R&D stock in year t

RDI_t = R&D investment in year t

Before measuring R&D stock with the above equation, we must consider following two factors. First, because the R&D process takes time and its effect does not directly yield to productivity, we must consider the time-lag structure. Second, with the emergence of superior technology, the value of a past innovation tends to depreciate. The depreciation rate for R&D for industries and countries are much more difficult than that for firms. When a firm loses its distinct advantage brought by the technology, the losses also affect the society as a whole.

(b) $$RDS_t = RDI_t + (1-\delta)RDS_{t-1}$$

Where, $RDI_t = \sum_{i=1}^{n} \mu_i E_{t-i}$

RDS_t = R&D stock in year t

RDI_t = Knowledge flow in year t

E_{t-i} = real R&D investment in year t-i

δ = R&D depreciation rate

In equation (b), “i" denotes 1 year, meaning that a new knowledge flow in year t is going to be in the form of real R&D investment in year t-1. Also, a 1% yearly depreciation rate was used for all industries.

We can also calculate the base year R&D stock as follows:

(c) $$RDS_0 = \frac{RDI_0}{g+\delta}$$

Where, RDS_0 = volume of R&D stock in base year

RDI_0 =R&D investment in base year

g = average growth of R&D investment

4.2 Measuring Patent Propensity

One of the most critical elements in this research is the analysis of the contribution of IPR to R&D in a sequential setting. We used patent propensity proxy as the ratio between patent stocks and R&D stocks. Because different industries have different patenting activities, we believe this measure will be able to capture the level of property rights granted (patent propensity) on the available knowledge that has accumulated in each industry.

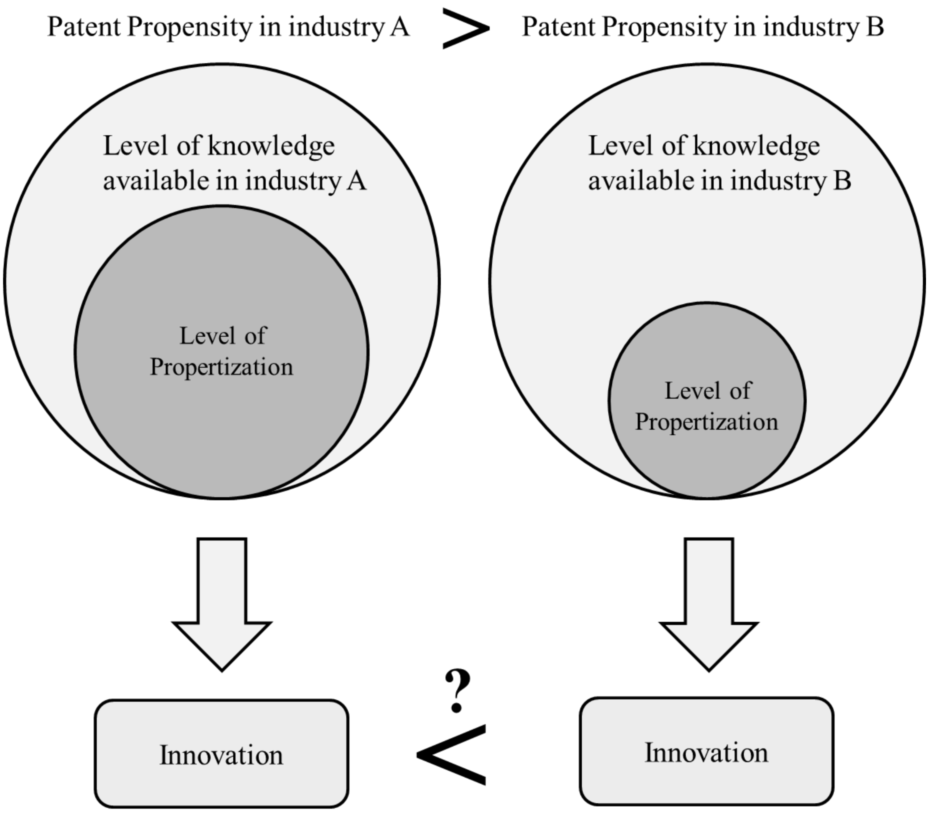


Figure 2. Level of Patent Propensity

Figure 2 shows an example of the level of patent propensity of the known knowledge in industry A and industry B. With these ratios as explanatory variables on R&D, we are able to analyze how different levels of patent propensity influence R&D investment in different industries. A negative sign for this variable can signify “too much” patenting discouraging innovation, whereas for a positive sign, we can expect that a higher level of patent propensity actually contributes to the role of IPR in stimulating R&D activity.

(a) $PP_{ijt} = PTS_{ijt} / RDS_{ijt}$

As explained above, equation (a) measures the level of patent propensity in industry i, country j during t year. Finally, the following variables capture its effect on R&D investment.

(b) $IPR_{jt} * PP_{ijt}$

A positive sign of this coefficient suggests that strong patent propensity would allow IPR to enhance R&D activities, thereby contributing to long-term economic growth. Despite the fact that some knowledge in our society is 'propertized' under patents, patents at the same time disclose ideas and innovations to the public, acting as an effective diffusion mechanism. Therefore, the fundamental role of IPR could actually enhance innovation activities under these circumstances. On the other hand, a negative sign may support the theoretical works of James Bessen and Hunt (2007), supporting the claim that a strong IPR regime actually hinders innovation when innovation is 'sequential.'

4.2.1 Measuring patent stocks

Measuring patent stocks for different industries and different countries requires the gathering of data from different patent offices. Ideally, this method would ensure the accurate measurement of the “patent propensity” of knowledge in each country in different industries. However, it is very difficult actually to obtain patent application data for different technology domains in 11 different countries. Only USPTO and EPO have enough data from the 1980s, which were classified in the IPC (international patent classification) manner. Therefore, instead of using data from each country’s patent office, we used data from different countries who filed their patents with the Patent Cooperation Treaty (PCT). Using PCT data yields some unexpected distortion, as patents filed with the PCT do not fully capture the level of patents filed with a domestic patent office. For example, in the US, more than 50% of patents filed are by foreign applicants. Thus, our measurement does not capture the other 50%. PCT data only captures the nationality of the applicants. Despite this weakness, there are some benefits of using PCT data instead of using data from domestic patent offices. Because patents that are filed with the PCT have a high probability of being subject to exports, the PCT data may capture more valuable patents instead of capturing the number of useless patents filed in a domestic patent office.

Because patent data is not classified at the industry level, measuring patent stocks for different industries requires the matching of the level of concordance between the International Patent Classification (IPC) scheme and the International Standard Industry Classification (ISIC) scheme. Most countries adopt IPC for their standard patent classification system, with the few exceptions of some countries using both IPC and their own classification. Currently, the Canadian Intellectual Property Office is the only office that uses a patent classification scheme according to industrial use. Based on the Canadian industrial classification, Kortum and Putnam (1997) constructed the Yale Technology Concordance (YTC) with conditional probabilities from the Canadian data and then applied this to patents in other countries or in time periods where only the technology field of the patents is available. Because YTC was basically formed from the Canadian SIC, when applied to other countries, it is difficult to match it with ISIC data accurately.

Unlike YTC, technology concordance developed by the Fraunhofer Institute for Systems and Innovation research (FhG-ISI), Observatoire des Sciences et des Techiques (OST), and Science and Policy Research Unit (SPRU) attempts to assign IPC codes with NACE and ISIC classification schemes (Schmoch, Laville, Patel, & Frietsch, 2003). We henceforth abbreviate this technique as FOS concordance (FhG-ISI, OST, SPRU). The FOS concordance table only matches IPC classifications to NACE classifications, and our R&D investment data are from the ISIC (rev. 3) classification. However, the NACE classification is nearly identical to the ISIC rev. 3 classification; especially regarding the use of four industries, the classification was identical. Table 1 shows the FOS concordance between the IPC and NACE classification schemes as used here for constructing patent data for the four industries of the Chemical (including pharmaceutical), machine, electronics, and transport equipment industries.

Table 1. FOS Concordance table for 4 industries

Industry	Field Name	NACE	IPC Subclasses
Chemicals	Basic chemical	24.1	B01J, B09B, B09C, B29B, C01B, C01C, C01D, C01F, C01G, C02F, C05B, C05C, C05D, C05F, C05G, C07B, C07C, C07F, C07G, C08B, C08C, C08F, C08G, C08J, C08K, C08L, C09B, C09C, C09D, C09K, C10B, C10C, C10H, C10J, C10K, C12S, C25B, F17C, F17D, F25J, G21F
	Pesticides & agro-chemical products.	24.2	A01N
	Paints, varnishes	24.3	B27K
	Pharmaceuticals	24.4	A61K, A61P, C07D, C07H, C07J, C07K, C12N, C12P, C12Q
	Soaps, detergents, toilet preparations	24.5	C09F, C11D, D06L
	Other chemicals	24.6	A62D, C06B, C06C, C06D, C08H, C09G, C09H, C09J, C10M, C11B, C11C, C14C, C23F, C23G, D01C, F42B, F42D, G03C
	Man-made fibres	24.7	D01F
Machine	Energy machinery	29.1	B23F, F01B, F01C, F01D, F03B, F03C, F03D, F03G, F04B, F04C, F04D, F15B, F16C, F16D, F16F, F16H, F16K, F16M, F23R
	Non-specific purpose machinery	29.2	A62C, B01D, B04C, B05B, B61B, B65G, B66B, B66C, B66D, B66F, C10F, C12L, F16G, F22D, F23B, F23C, F23D, F23G, F23H, F23J, F23K, F23L, F23M, F24F, F24H, F25B, F27B, F28B, F28C, F28D, F28F, F28G, G01G, H05F
	Agricultural and forestry machinery	29.3	A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01M, B27L
	Machine-tools	29.4	B21D, B21F, B21H, B21J, B23B, B23C, B23D, B23G, B23H, B23K, B23P, B23Q, B24B, B24C, B25D, B25J, B26F, B27B, B27C, B27F, B27J, B28D, B30B, E21C
	Special purpose machinery	29.5	A21C, A22B, A22C, A23N, A24C, A41H, A42C, A43D, B01F, B02B, B02C, B03B, B03C, B03D, B05C, B05D, B06B, B07B, B07C, B08B, B21B, B22C, B26D, B31B, B31C, B31D, B31F, B41B, B41C, B41D, B41F, B41G, B41L, B41N, B42B, B42C, B44B, B65B, B65C, B65H, B67B, B67C, B68F, C13C, C13D, C13G, C13H, C14B, C23C, D01B, D01D, D01G, D01H, D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C, D05B, D05C, D06B, D06G, D06H, D21B, D21D, D21F, D21G, E01C, E02D, E02F, E21B, E21D, E21F, F04F, F16N, F26B, H05H
	Weapons and ammunition	29.6	B63G, F41A, F41B, F41C, F41F, F41G, F41H, F41J, F42C, G21J
	Domestic appliances	29.7	A21B, A45D, A47G, A47J, A47L, B01B, D06F, E06C, F23N, F24B, F24C, F24D, F25C, F25D, H05B
Electronics	Office machinery and computers	30	B41J, B41K, B43M, G02F, G03G, G05F, G06C, G06D, G06E, G06F, G06G, G06J, G06K, G06M, G06N, G06T, G07B, G07C, G07D, G07F, G07G, G09D, G09G, G10L, G11B, H03K, H03L
	Electric motors, generators, transformers	31.1	H02K, H02N, H02P
	Electric distribution, control, wire, cable	31.2, 31.3	H01H, H01R, H02B
	Accumulators, battery	31.4	H01M
	Lighting equipment	31.5	F21H, F21K, F21L, F21M, F21S, F21V, H01K
	Other electrical equipment	31.6	B60M, B61L, F21P, F21Q, G08B, G08G, G10K, G21C, G21D, H01T, H02H, H02M, H05C
	Electronic components	32.1	B81B, B81C, G11C, H01C, H01F, H01G, H01J, H01L
	Signal transmission, telecommunications	32.2	G09B, G09C, H01P, H01Q, H01S, H02J, H03B, H03C, H03D, H03F, H03G, H03H, H03M, H04B, H04J, H04K, H04L, H04M, H04Q, H05K
	Television and radio receivers, audiovisual electronics	32.3	G03H, H03J, H04H, H04N, H04R, H04S
Transports	Motor vehicles	34	B60B, B60D, B60G, B60H, B60J, B60K, B60L, B60N, B60P, B60Q, B60R, B60S, B60T, B62D, E01H, F01L, F01M, F01N, F01P, F02B, F02D, F02F, F02G, F02M, F02N, F02P, F16J, G01P, G05D, G05G
	Other transport equipment	35	B60F, B60V, B61C, B61D, B61F, B61G, B61H, B61J, B61K, B62C, B62H, B62J, B62K, B62L, B62M, B63B, B63C, B63H, B63J, B64B, B64C, B64D, B64F, B64G, E01B, F02C, F02K, F03H

Source: Linking technology areas to industrial sectors. Final Report to the European Commission (2003)

After matching the IPC-classified patents to NACE-classified industries for each country, data was then processed to construct patents stocks with a method identical to that of constructing R&D stocks. The constructed patent stocks were then divided by each corresponding R&D stock, finally forming the patent propensity equation $PP_{ijt} = PTS_{ijt} / RDS_{ijt}$. Figure 3 shows the average patent propensity trends (patent stocks-R&D stocks ratio, with depreciation rate equal 10%) for four different industries from 1995 to 2005.

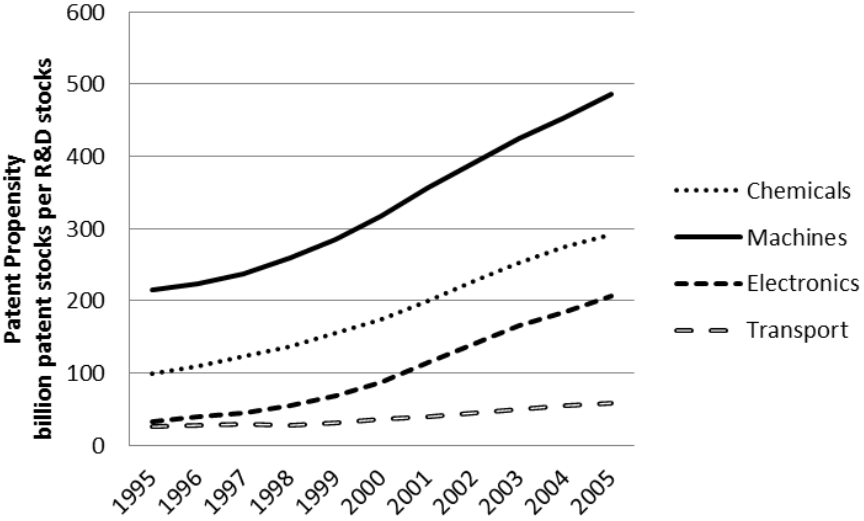


Figure 3. Average Patent Propensity Trend in 4 Industries (Note: because perfectly balanced data does not exist from 1987, the graph above only shows the yearly trend from year 1995) source: OECD

Figure 3 shows the yearly trend of average patent propensity in four different industries. Not surprisingly, the patent propensity in the electronics industry has increased tremendously since 1995, which coincides with the digital revolution which occurred during the 1990s and the early 2000s.

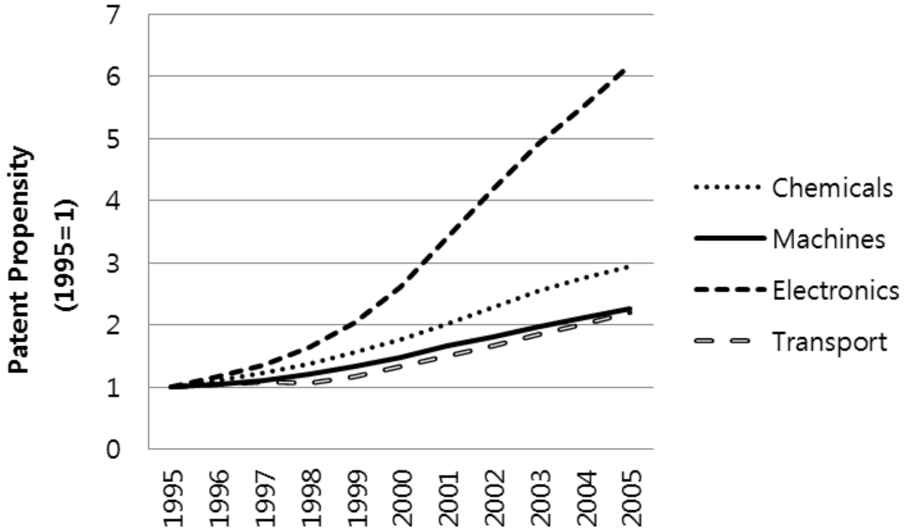


Figure 4. Constant Patent Propensity Comparison with base year 2005 source: OECD

Figure 4 shows the tremendous increase in the patent propensity level in the electronics industry. This sectoral comparison reveals some interesting characteristics of the industry. The electronic industry, which includes the semiconductor and computer machinery industries, are associated with what are referred to as complex-product technologies (WIPO, 2011). As explained above, we can expect more technological commercialization in the electronics industry because “complex” product industries are much more likely to use patents to force rivals into negotiation.

4.3 Intellectual Property Rights Index

Countries differ widely in the strength of the protection that they provide to intellectual property (Kanwar & Evenson, 2003). To measure the level of IPR for each country, the index developed by Walter G. Park and Ginarte (1997) was used. This patent rights index was developed for 110 countries for 1960-1990. However, because our analysis involves data from 1987-2005, the updated index from W.G. Park (2008) was used. This index is the un-weighted sum of five separate scores, which include coverage (inventions that are patentable), membership in international treaties, provisions for a loss of protection, the duration of protection, enforcement mechanisms and restrictions (e.g., compulsory licensing in the event that a patented invention is not sufficiently exploited) (W.G. Park, 2008). The Table 2 presents a different IPR index for 11 countries from 1987-2005 and Figure 5 shows the average IPR index for the 11 countries. TRIP agreements in 1995 were factored into the process of gradual harmonization of the level of IPR protection, and one can observe a sharp increase in the IPR index up to 1995. (Such a sharp increased can be observed in Australia, Czech Republic, Greece and Korea.)

Table 2. Park-Ginarte IPR Index (1985-2005)

	1985	1990	1995	2000	2005
Australia	2.49	3.28	4.17	4.17	4.17
Czech Republic			2.96	3.21	4.33
Denmark	3.63	3.88	4.54	4.67	4.67
Finland	3.31	3.31	4.42	4.54	4.67
Germany	3.84	3.97	4.17	4.50	4.50
Greece	2.33	2.87	3.47	3.97	4.30
Italy	3.68	4.01	4.33	4.67	4.67
Japan	3.43	3.88	4.42	4.67	4.67
Korea	2.65	3.69	3.89	4.13	4.33
Netherland	3.77	4.22	4.54	4.67	4.67
U.K.	3.88	4.34	4.54	4.54	4.54
U.S.A.	4.68	4.68	4.88	4.88	4.88
Average IPR index (excluding Czech)	3.43	3.83	4.31	4.49	4.55

Source: International patent protection: 1960-2005 (W.G. Park, 2008).

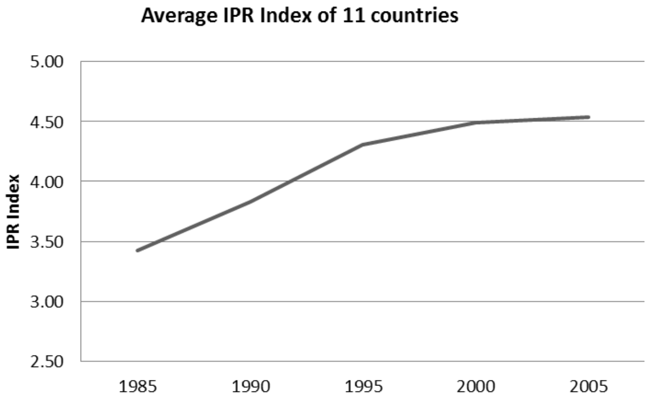
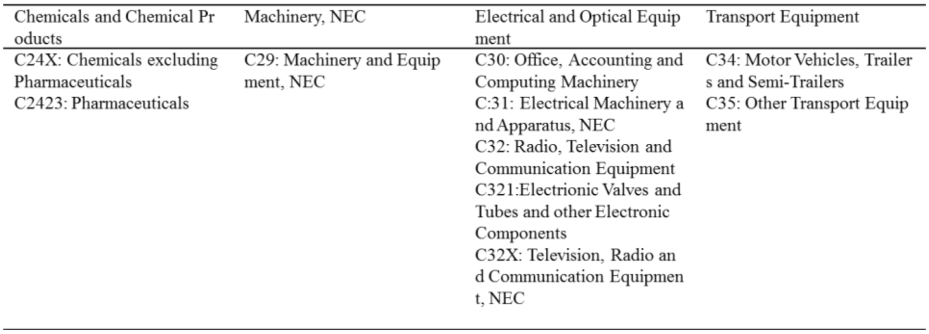


Figure 5. Average IPR Index of 11 countries, Source: International patent protection: 1960-2005 (W.G. Park, 2008). (Note that Czech Republic was excluded because of its insufficient data.)

4.4 Data and Descriptive Statistics

The panel data was constructed with four industries with a cross-country sample of 11 countries. The four industries are the chemical and chemical product, the electrical and optical equipment, the machinery and equipment, and the transport equipment industries. The table below shows the corresponding sub-categories for the four industries.

Table 3. Sector Classification for 4 Industries



Chemicals and Chemical Products	Machinery, NEC	Electrical and Optical Equipment	Transport Equipment
C24X: Chemicals excluding Pharmaceuticals C2423: Pharmaceuticals	C29: Machinery and Equipment, NEC	C30: Office, Accounting and Computing Machinery C:31: Electrical Machinery and Apparatus, NEC C32: Radio, Television and Communication Equipment C321:Electrionic Valves and Tubes and other Electronic Components C32X: Television, Radio and Communication Equipment, NEC	C34: Motor Vehicles, Trailers and Semi-Trailers C35: Other Transport Equipment

Source: ISIC rev.3

The unbalanced panel data covers the period of 1987-2005. Therefore, this period may feasibly reflect the tremendous rise in patenting during the 1990s. Value-added industries, capital stocks, and total labor-hour data were collected from EU KLEMS, which provides data for nearly all OECD countries. However, not many countries provided capital stocks data; therefore, only 11 countries[1] were selected as the country sample. R&D

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[1] The author was not able to collect data for developing countries, as industrial sectoral data were only provided the OECD nations. Also, for some reason, EU

investment, PCT patents, GDP, and foreign currency data for the 11 countries was collected from the OECD and the 2005 deflators for the 11 countries were collected from the IMF. The IPR index is from the IPR data of W.G. Park (2008). Finally, all of the data was deflated and converted to 2005 USD. Table 4 and Table 5 show descriptions of the variables for the simultaneous equations.

Table 4. Descriptions of variables for R&D investment equations

Variables	Descriptions
RDI	Log of R&D investment in corresponding industry/country (each year; in constant 2005 USD)
RDS	Log of R&D stocks in corresponding industry/country (each year; in constant 2005 USD,)
VA	Log of value added in corresponding industry/country (each year; in constant 2005 USD)
IPR	Log of IPR index in corresponding country (each year)
IPR*PP	Log of interaction term between IPR and PP
Industry dummies	4 industries

KLEMS capital data in many countries were classified; therefore, only data from the following 11 countries were collected: Australia, Czech, Denmark, Finland, Germany, Italy, Japan, Korea, Netherland, the UK, and the US.

Table 5. Descriptions of variables for the value-added equation

Variables	Descriptions
VA	Log of the value added in corresponding industry/country (each year; in constant 2005 USD)
K	Log of the capital stock in corresponding industry/country (each year; in constant 2005 USD)
L	The total hours worked by employees in corresponding industry/country (each year)
RDS	Log of the R&D stocks in corresponding industry/country (each year; in constant 2005 USD,)
IPR	Log of the intellectual property rights index in corresponding country (each year)
GDP	Log of the R&D GDP in corresponding country (each year; in constant 2005 USD)
Industry dummies	4 industries

Figure 6 and Figure 7 show the average R&D investments and average amount of value added to industry for the four industries. The transport equipment industry which includes, the automobile, shipbuilding, aircraft and railroad industries, showed by far the greatest amount of R&D investment followed by the electronics industry, chemical industry, and machine industries. In terms of value-added industries, the electronic industries had the largest amount of added value, followed by the transportation equipment industry, machine industry, and chemical industry. In addition, a simple R&D productivity comparison based on added value/R&D investment shows the machine industry as the most productive, while the transports equipment industry is shown as the least productive industry. Simple R&D productivities, represented as the ratio between added value and R&D, is shown in Figure 8. The transport equipment industry had the lowest productivities, while the machine industry was the most productive. Table 6 introduces the descriptive statistics for the four industries.

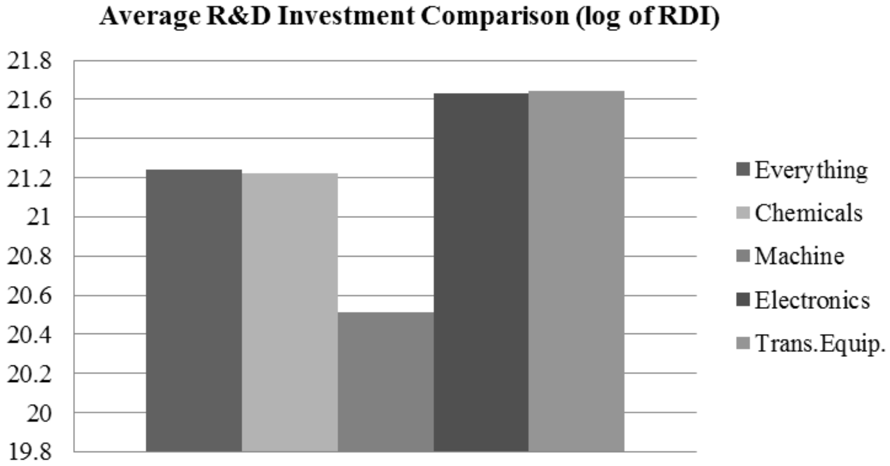

Figure 6. Average R&D Investment Comparison, Source: OECD.

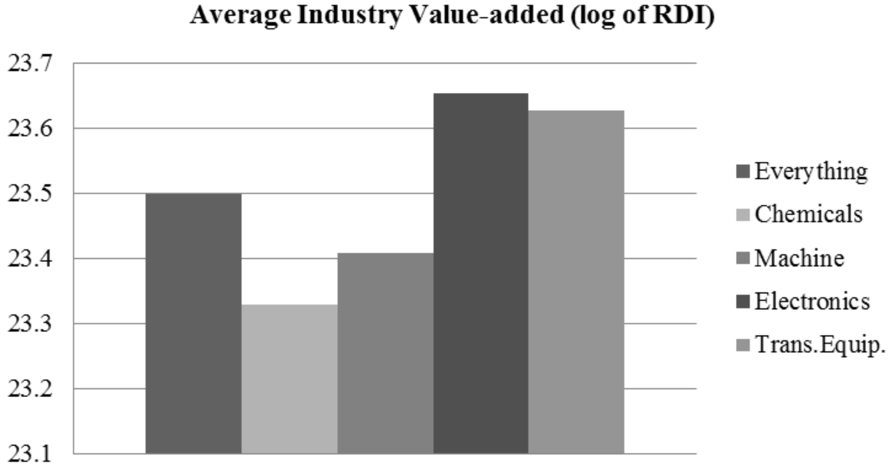

Figure 7. Average Industry Value-added, Source: OECD

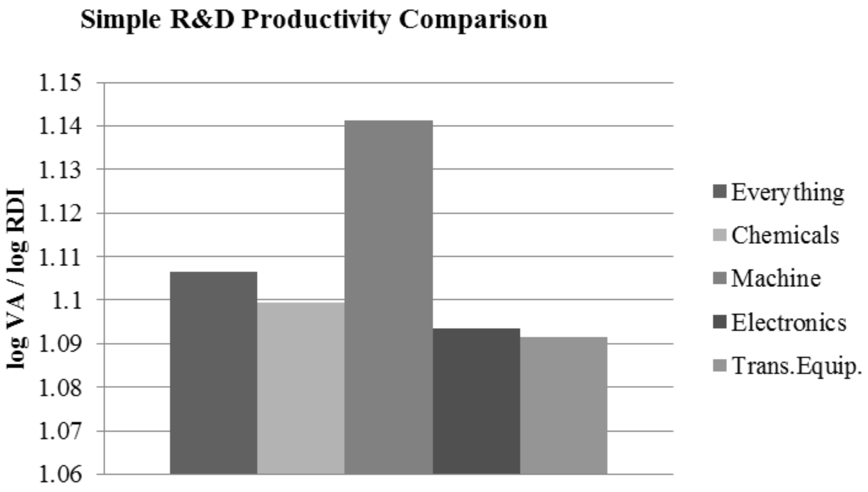

Figure 8. Simple R&D Productivity Comparison, Source: OECD

Table 6. Descriptive Statistics for 4 industries

	Combined		**Chemicals**		**Machine**		**Electronics**		**Trans. Equip.**	
	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
RDI	21.238	0.070	21.222	0.132	20.513	0.115	21.632	0.150	21.645	0.146
VA	23.498	0.059	23.329	0.113	23.408	0.108	23.653	0.126	23.627	0.127
RDS	25.070	0.084	24.929	0.149	23.903	0.135	25.791	0.177	25.763	0.174
IPR	1.451	0.004	1.449	0.009	1.457	0.008	1.450	0.009	1.447	0.009
IPR*PP	1.624	0.007	1.651	0.012	1.726	0.013	1.574	0.012	1.531	0.011
K	23.975	0.060	24.066	0.107	23.633	0.116	23.980	0.131	24.253	0.121
L	19.917	0.055	19.307	0.100	20.080	0.097	20.178	0.117	20.166	0.112
GDP	27.603	0.050	27.472	0.101	27.565	0.100	27.589	0.101	27.816	0.098
Observations	691		185		177		174		155	

Note: Unit: 2005 constant USD (RDI, VA, RDS(1), K, GDP: deflated with base year 2005; GDP deflator for 12 countries is from the IMF.

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Table 7 shows the correlations among the variables for the simultaneous equations of RDI and VA for the corresponding industries. The RDI equations in general show high correlations between RDI and value-added industries (VA). This simple correlation suggests that the more industry invests in R&D, the greater value they receive in return. The fairly high correlations between value-added industries and R&D stocks in Table 8 suggest this regarding the role of R&D in general economic growth. We cannot discern here significant relationship between RDI and IPR, but the stronger correlation between RDI and IPR compared to that between VA and IPR appears to supports the conventional view of the role of IPR on innovation (suggesting that IPR increases R&D activities, which then stimulates economic growth). Table 9 to Table 16 represent the variable correlations for the corresponding industries.

Table 7. Bivariate correlation coefficients for R&D investment equation for 4 industries combined

	RDI	RDS(1)	VA	IPR	IPR*PP(1)
RDI	1.000				
RDS	0.879	1.000			
VA	0.926	0.822	1.000		
IPR	0.510	0.516	0.494	1.000	
IPR*PP	0.050	-0.096	0.099	0.718	1.000

Table 8. Bivariate correlation coefficients of Value added equation for 4 industries combined

	VA	K	L	RDS	IPR	GDP
VA	1.000					
K	0.971	1.000				
L	0.933	0.897	1.000			
RDS	0.822	0.816	0.740	1.000		
IPR	0.494	0.455	0.316	0.516	1.000	
GDP	0.948	0.925	0.909	0.811	0.479	1.000

Table 9. Bivariate correlation coefficients of R&D investment equation for chemical industry

	RDI	RDS(1)	VA	IPR	IPR*PP
RDI	1.000				
RDS	0.879	1.000			
VA	0.955	0.869	1.000		
IPR	0.576	0.575	0.516	1.000	
IPR*PP	0.237	0.068	0.181	0.795	1.000

Table 10. Bivariate correlation coefficients of value-added equation for chemical industry

	VA	K	L	RDS(1)	IPR	GDP
VA	1.000					
K	0.988	1.000				
L	0.954	0.942	1.000			
RDS	0.869	0.876	0.785	1.000		
IPR	0.516	0.481	0.357	0.575	1.000	
GDP	0.971	0.960	0.970	0.810	0.456	1.000

Table 11. Bivariate correlation coefficients of R&D investment equation for machine industry

	RDI	RDS	VA	IPR	IPR*PP
RDI	1.000				
RDS	0.889	1.000			
VA	0.959	0.872	1.000		
IPR	0.530	0.384	0.458	1.000	
IPR*PP	0.148	-0.045	0.058	0.853	1.000

Table 12. Bivariate correlation coefficients of value-added equation for machine industry

	VA	K	L	RDS	IPR	GDP
VA	1.000					
K	0.978	1.000				
L	0.917	0.931	1.000			
RDS	0.872	0.825	0.857	1.000		
IPR	0.458	0.409	0.236	0.384	1.000	
GDP	0.925	0.894	0.915	0.871	0.399	1.000

Table 13. Bivariate correlation coefficients of R&D investment equation for electronic industry

	RDI	RDS	VA	IPR	IPR*PP
RDI	1.000				
RDS	0.857	1.000			
VA	0.911	0.867	1.000		
IPR	0.521	0.589	0.493	1.000	
IPR*PP	0.164	0.103	0.131	0.786	1.000

Table 14. Bivariate correlation coefficients of value-added equation for electronic industry

	VA	K	L	RDS	IPR	GDP
VA	1.000					
K	0.986	1.000				
L	0.962	0.957	1.000			
RDS	0.867	0.863	0.790	1.000		
IPR	0.493	0.487	0.325	0.589	1.000	
GDP	0.944	0.943	0.913	0.896	0.489	1.000

Table 15. Bivariate correlation coefficients of R&D investment equation for Transport Equipment Industry

	RDI	RDS	VA	IPR	IPR*PP
RDI	1.000				
RDS	0.875	1.000			
VA	0.964	0.810	1.000		
IPR	0.514	0.680	0.523	1.000	
IPR*PP	0.135	0.099	0.223	0.676	1.000

Table 16. Bivariate correlation coefficients of value-added equation for transport equipment industry

	VA	K	L	RDS	IPR	GDP
VA	1.000					
K	0.973	1.000				
L	0.962	0.944	1.000			
RDS	0.810	0.771	0.762	1.000		
IPR	0.523	0.482	0.380	0.680	1.000	
GDP	0.970	0.940	0.921	0.850	0.611	1.000

4.5 Regression Models

4.5.1 Basic regressions

As explained above, the simultaneous equation consists of the two equations of the RDI equation and the VA equation. After taking the log of both sides of the Cobb-Douglas production functions, the RDI equation becomes

$$\begin{aligned} \mathrm{logRDI}_{ijt} = {} & \alpha_i + \beta_1 \mathrm{logVA}_{ijt} + \beta_2 \log RDS_{itj} \\ & + \beta_4 \mathrm{logIPR}_{jt} (\beta_5 + \beta_6 \mathrm{logSQ}_{ijt}) + \varepsilon_{ijt} \end{aligned} \quad \cdots\cdots\cdots \quad \text{(a)}$$

which becomes, equation (b)

$$\begin{aligned} \mathrm{logRDI}_{ijt} = {} & \alpha_i + \beta_1 \mathrm{logVA}_{ijt} + \beta_2 \log RDS_{itj} \\ & + \beta_4 \beta_5 \mathrm{logIPR}_{jt} + \beta_4 \beta_6 \mathrm{logSQ}_{ijt} + \varepsilon_{ijt} \end{aligned} \quad \cdots\cdots \quad \text{(b)}$$ [2]

And the VA equation becomes,

$$\begin{aligned} \mathrm{logVA}_{ijt} = {} & \alpha_i + \gamma_1 \mathrm{logK}_{jit} + \gamma_2 \mathrm{logL}_{ijt} + \gamma_3 \mathrm{logRDS}_{ijt} \\ & + \gamma_4 \mathrm{logIPR}_{jt} + \gamma_5 \mathrm{logGDP}_{jt} + \varepsilon_{ijt} \end{aligned} \quad \cdots\cdots\cdots \quad \text{(c)}$$

In these simultaneous equations, the two endogenous variables are RDI

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[2] Note that country dummy variable α_j was dropped because the system always contains enough country-controlled variables such as IPR and GDP. IPR represents policy of corresponding country, and processing regression with country-fixed effects actually diluted the effects of IPR. Therefore, only industry-fixed effects were taken into account.

and VA. Ideally, we want to observe a virtuous cycle between IPR, R&D investment, and added value. However, because R&D is represented as RDS (R&D stocks) in equation (c), it is difficult to capture the “IPR to R&D of the R&D stocks” channel flow. The coefficient $\beta_4\beta_5$ from equation (b) captures the percent change in RDI for a 1% increase in the IPR, while $\beta_4\beta_6$ captures the percent change in RDI from a 1% change in the patent propensity caused by a strong IPR. Aggregate effects will be calculated to review the overall effects of IPR on RDI. For equation (c), γ_4 captures the direct contribution of a stronger IPR on the addition of value.

4.5.2 3SLS (three stage least square regression)

The simultaneous equations (b) and (c) contain two endogenous variables: RDI and VA. The explanatory variable VA is jointly determined with the dependent variable. The problem of simultaneous equations is that when OLS is used to estimate the parameter, we face an error in the variable problem. Therefore, with a simple OLS regression, the estimations would be biased and inconsistent. There are two main methods to resolve error in variables problems. The 2sls (the two-stage least-squares) method can be implemented. However, 3SLS (the three-stage least squares) method goes one step further by using a two-stage least-squares estimated moment matrix of the structural disturbance to estimate all coefficients of the entire system simultaneously (Zellner & Theil, 1962). Therefore, in order to the capture dynamic structures of the IPR-R&D-VA virtuous cycles, the 3SLS method was implemented, as this method captures the relationship between the two structural equations using their structural disturbances simultaneously.

Chapter5. Empirical Results

Table 17 represents the combined simultaneous equation results in the four industries. Equation m1 (model 1) presents the equation with IPR as the explanatory variable, as represented in the first column, while m2 (model 2) includes both IPR and its interaction with patent propensity variables, as represented in the second column. The left column of each table corresponds to the R&D investment (RDI) equation of the simultaneous equations, while the right column of each table corresponds to the value-added industry (VA) equation of the simultaneous equations.

First, we consider the results of model 1 using the RDI equation in combined industries, as represented by Table 17. IPR has a statistically significant influence on R&D investment. R&D investment increases by 0.74% according to a 1% increase in the IPR index. This result is in accordance with conventional economic literature pertaining to IPR, which argues that IPR enhances incentives for innovation, thereby increasing R&D activities. Similar empirical results of the positive relationship between IPR and RDI can be found in the empirical works of Walter G. Park and Ginarte (1997) and Kanwar and Evenson (2003). The important part of this research was to capture whether a stronger IPR regime hinders sequential innovations. As explained earlier, in model 2 the patent propensity index was formulated in order to capture such activities. However, the empirical results in model 2 suggest quite a different story. The sign of the coefficient of IPR, represented as $\beta_4\beta_5$ from equation (b), was negative, while the sign of the interaction term between IPR and patent propensity, represented as $\beta_4\beta_6$, was positive. The empirical results suggest that higher patent propensity with strong IPR actually enhances R&D activities, which is empirically opposite of the theory by J. Bessen and Maskin (2006). The higher patent propensity suggests that much of our knowledge is actually protected by IPR. Under a stronger IPR regime, the higher patent propensity actually enhances sequential innovation activities. A possible explanation for this result is that it may actually capture the positive role of IPR, which is to reveal knowledge to the public. Also, regarding sequential innovation, James Bessen and Maskin (2009) drew attention to particular industries, such as the software industry. The combined industry results may be too diluted to capture such sectoral effects. The negative sign of IPR can also represent an interesting result. IPR alone can actually discourage R&D activity, but with a higher patent propensity level, IPR can enhance R&D activities. In order for IPR to be effective in R&D activities, vigorous patent activities are required in advance. This result is in fair accordance with the result of Walter G. Park and Ginarte (1997). Park argued that the level of development was crucial for IPR to perform its incentive mechanism as regards R&D activities. His results showed that that the economies of developed nations had higher and statically significant contributions from IPR, while developing nations enjoyed a minor effect of IPR. The negative IPR signs and the positive interaction sign in model 2 of Table 17 suggest that prior technological capabilities are essential for the incentive mechanism of IPR to operate properly. The overall effect of IPR, as represented by $\beta_4\beta_5 + \beta_4\beta_6$, has a positive coefficient of 0.47, meaning that strong IPR in general enhances the R&D activities in combined industries.

Because our research also focuses on the virtuous cycle between IPR, RDI, and VA, the second equation represents how value-added factors are influenced by R&D stocks and IPR. First, the role of IPR in the VA equations in Table 17 was also statically significant when it comes to adding value. In our model, this effect captures the direct contribution of IPR on the economy. The coefficient of IPR is 0.974 in model 1 and 0.966 in model 2. As explained earlier, such evidence may capture technological commercialization activities. A sudden increase in IPR itself does not contribute to value-added factors as regards increased R&D stocks; rather, such activity can yield a revenue effect from the increased market value of intangible assets such as patents, thereby increasing the chance of technological commercialization activities (Motohashi, 2008). Also, the variable RDS (R&D stocks) also has a positive significant coefficient, which implies that industries' stocks of knowledge inspired under strong IPR actually contributes to a higher added value.

Finally, we want to compare the direct and indirect effects of IPR on value-added industries. Indirect effects are represented by the IPR coefficient of RDI of the first equation times the RDS coefficient of the second equation. Because a 'stock of knowledge' is composed of augmented R&D investments, we can assume that multiplication between the IPR coefficient of the first equation (RDI equation) and the RDS coefficient of the second equation (VA equation) represents the indirect effect of the IPR on value-added industries. For combined industries, the direct effect of IPR, which is 1.413, is considerably greater than the indirect effect, which is 0.4829. Regarding the contribution to value-added industries, the traditional role of IPR, which is to induce R&D investments, was in fact less significant than the direct effect of IPR.

Table 17. 3SLS regression analysis of simultaneous equation of R&D Investments and Value-added for combined industries

RDI	m1	m2	VA	m1	m2
VA	0.798***	0.785***	K	0.527***	0.533***
	(0.030)	(0.030)		(0.020)	(0.020)
RDS(1)	0.217***	0.271***	L	0.270***	0.265***
	(0.020)	(0.030)		(0.020)	(0.020)
IPR	0.741***	-0.900*	RDS	0.026**	0.026**
	(0.220)	(0.530)		(0.010)	(0.010)
IPR*PP		1.097***	IPR	0.974***	0.966***
		(0.320)		(0.110)	(0.110)
Elec. dummy	0.520***	0.576***	GDP	0.201***	0.199***
	(0.070)	(0.070)		(0.020)	(0.020)
Trans. dummy	0.562***	0.662***	Elec. dummy	-0.011	-0.013
	(0.070)	(0.070)		(0.030)	(0.030)
Chem. dummy	0.556***	0.569***	Trans. dummy	0.221***	0.224***
	(0.060)	(0.060)		(0.030)	(0.030)
Constant	4.427***	4.917***	Chem. dummy	-0.099**	-0.105**
	(0.350)	(0.360)		(0.040)	(0.040)
			Constant	2.057***	2.043***
				(0.250)	(0.250)
Observations	691	691	Observations	691	691
R^2	0.914	0.917	R^2	0.977	0.977

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level, standard errors in parenthesis.

Tables 18 to 21 represent the impact of IPR on R&D investments and value-added factors for the four different industries. For the machine industry, a country dummy for total labor hours including the Czech Republic and Korea was implemented, as shown in Figure 9, as these samples were serious outliers. After implementing a dummy variable, the negative sign problem of total labor hours was resolved.

First, considering chemical industries, IPR by itself is a significant contributor to R&D investment, while when combined with patent propensity, these two values are not significant. This result infers that patent propensity has no relationship with R&D investment in the chemical industry. The coefficient for IPR for the machine industry was 1.666, the greatest among the four industries. Also, patent propensity was only positively significant for the machine industry, meaning that a greater number of patents in the machine industry would actually enhance R&D investment.

Surprisingly, IPR and patent propensity was not related to R&D investments in the electronic industry. This surprising result sheds light on the ongoing dispute regarding the role of the IPR on sequential innovation in the electronic industry. Survey data by Levin et al. (1987) from the electronics industry indicates that the “lead-time advantage” and the action of “moving down the learning curve quickly” provide more effective protection than patents (J. Bessen & Maskin, 2006). Therefore, the empirical result pertaining to the electronic industry appears to support Levin’s survey, which argued that electronic firms tend to utilize their R&D investments on patents over other mechanisms. Also, the theory of J. Bessen and Maskin (2006) suggests that “sequential” patent protection is not as useful for encouraging innovation as it would be in a static setting, especially in innovative industries such as the software and semiconductor industries. The electronics industry classification includes innovative sectors such as the semiconductor industry. The current result implies that indeed IPR is not as useful for encouraging R&D investment in the electronics industry.

The transportation equipment industry, on the other hand, shows a negative coefficient value for IPR, meaning that stronger IPR actually hinders R&D investment in transportation equipment. Overall, the empirical results show that both the chemical and machine industries have positive values of IPR and that the electronics industry shows no significant relationship between IPR and R&D investment. In addition, the transport equipment industry shows negative effects of IPR on R&D investment. This evidence is somewhat in agreement with the analysis of the Carnegie Mellon survey conducted by Cohen (2000). The survey suggested that chemical industries should consider patents as an important source of appropriation, while the electronics equipment industries face insufficient appropriation regarding their patents. Moreover the survey suggests that secrecy, instead of a patent, is commonly the dominant mechanism, as in the chemical and semiconductor industries.

The empirical evidence of the value-added equations suggests that all industries except for the transport equipment industry show a positive effect of IPR on value-added industries. The electronics industry by far had IPR coefficients with the greatest values, followed by the chemical and machine industries. The IPR value for the transport equipment industry was not significant, suggesting no substantial relationship between IPR and value-added factors in that industry. The positive sign of IPR for the electronics industry can possibly be capturing the positive revenue effects through technology commercialization. This empirical result is not surprising, as the electronic industry is where the most of our technological commercialization and licensing activities are taking place. When comparing the direct and indirect effects of the IPR, direct effects turned out to be greater in the chemical industry, while indirect effects were greater in the machine industry. Calculations for the other two industries were not possible due to the insignificant coefficients of the explanatory variables. This empirical result suggests that the traditional role of IPR is more evident in the machine industry.

Table 18. 3SLS regression analysis of simultaneous equation of R&D Investments and Value-added for chemical industries

RDI	m1	m2	VA	m1	m2
VA	0.835***	0.823***	K	0.562***	0.568***
	(0.050)	(0.060)		(0.040)	(0.040)
RDS	0.180***	0.223***	L	0.266***	0.253***
	(0.040)	(0.060)		(0.040)	(0.040)
IPR	1.371***	0.787	RDS	0.028*	0.025*
	(0.380)	(0.540)		(0.010)	(0.010)
IPR*PP		0.013	IPR	1.030***	1.014***
		(0.010)		(0.150)	(0.150)
Constant	4.748***	4.864***	GDP	0.193***	0.204***
	(0.600)	(0.590)		(0.040)	(0.050)
			Constant	2.810***	2.925***
				(0.370)	(0.380)
Observations	185	185	Observations	185	185
R^2	0.925	0.929	R^2	0.984	0.990

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level, standard errors in parenthesis.

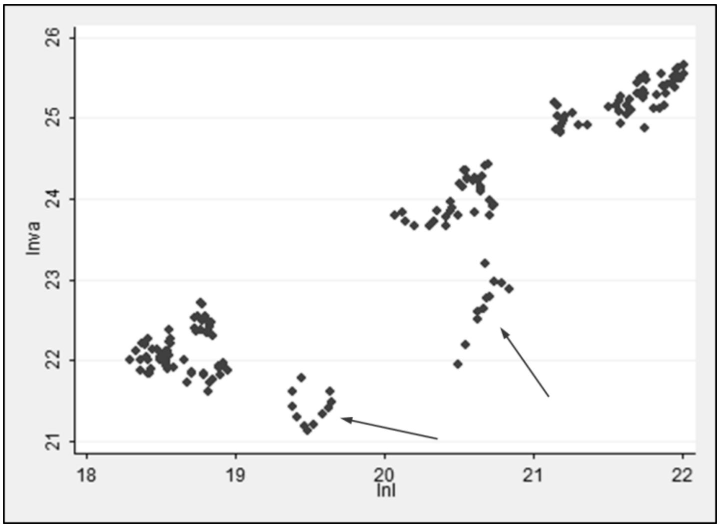

Figure 9. Correlation graph between value-added and total labor hours

Table 19. 3SLS regression analysis of simultaneous equation of R&D Investments and Value-added for machine industries

RDI	m1	m2	m3	VA	m1	m2	m3
VA	0.723***	0.748***	0.775***	K	0.743***	0.383***	0.380***
	(0.040)	(0.040)	(0.040)		(0.030)	(0.040)	(0.040)
RDS	0.214***	0.198***	0.237***	L	0.189***	0.526***	0.533***
	(0.030)	(0.030)	(0.030)		(0.050)	(0.070)	(0.070)
IPR	1.713***	1.666***	-0.548	RDS	0.123***	0.035**	0.034**
	(0.280)	(0.280)	(0.830)		(0.020)	(0.020)	(0.020)
IPR*PP			1.408**	IPR	0.292	0.796***	0.803***
			(0.500)		(0.190)	(0.150)	(0.150)
Constant	-4.022***	-4.149***	-4.923***	GDP	0.242***	0.014	0.01
	(0.490)	(0.490)	(0.550)		(0.040)	(0.030)	(0.030)
				Czech/ROK		0.905***	0.912***
						(0.080)	(0.080)
				Constant	-0.372	1.556***	1.586***
					(0.390)	(0.340)	(0.340)
Observations	177	177	177	Observations	177	177	177
R^2	0.943	0.943	0.945	R^2	0.978	0.987	0.987

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level, standard errors in parenthesis.

Table 20. 3SLS regression analysis of simultaneous equation of R&D Investments and Value-added for electronic industries

RDI	m1	m2	VA	m1	m2
VA	0.758***	0.739***	K	0.429***	0.431***
	(0.070)	(0.080)		(0.050)	(0.050)
RDS	0.238***	0.291***	L	0.437***	0.432***
	(0.060)	(0.070)		(0.050)	(0.050)
IPR	0.75	-0.948	RDS	0.040**	0.039**
	(0.630)	(1.510)		(0.020)	(0.020)
IPR*PP		1.107	IPR	1.126***	1.117***
		(0.890)		(0.220)	(0.220)
Constant	-3.515***	-3.708***	GDP	0.084*	0.089*
	(0.980)	(0.980)		(0.050)	(0.050)
			Constant	-0.429	-0.487
				(0.570)	(0.580)
Observations	174	174	Observations	174	174
R^2	0.849	0.851	R^2	0.980	0.980

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level, standard errors in parenthesis.

Table 21. 3SLS regression analysis of simultaneous equation of R&D Investments and Value-added for transportation equipment industries

RDI	m1	m2	VA	m1	m2
VA	0.830***	0.814***	K	0.328***	0.339***
	(0.030)	(0.040)		(0.040)	(0.040)
RDS	0.311***	0.350***	L	0.342***	0.352***
	(0.030)	(0.040)		(0.050)	(0.050)
IPR	-1.771***	-2.037***	RDS	-0.013	-0.012
	(0.330)	(0.370)		(0.020)	(0.020)
IPR*PP		0.01	IPR	0.346	0.407
		(0.010)		(0.260)	(0.260)
Constant	-3.404***	-3.739***	GDP	0.518***	0.489***
	(0.470)	(0.470)		(0.060)	(0.060)
			Constant	-5.805***	-5.572***
				(0.600)	(0.600)
Observations	155	155	Observations	155	155
R^2	0.961	0.962	R^2	0.981	0.981

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level, standard errors in parenthesis.

Chapter6. Conclusion

6.1 Conclusion and Implications

After the TRIP agreement in 1995, we observed substantial increases in global and unilateral intellectual property rights regimes. The research focused on the role of IPR and its interaction with patent propensity on innovations. Our results suggests that IPR in general, enhances economic growth indirectly by providing R&D incentives, while its direct effects contribute added value by possibly providing technological commercialization activities. The positive effects of patent propensity on R&D investments suggest the importance of prior technological capabilities in utilizing the positive incentive mechanisms of IPR. Therefore, while IPR alone can deter R&D investment, IPR with firm patent propensity can enhance the R&D investments; the empirical analysis showed that the overall IPR effects on R&D activities were positive. This result introduces insight about the fundamental role of IPR. Catch-up countries cannot promote innovation solely through an enhancement of their intellectual property rights regimes. With insufficient technological capabilities (from low patent propensity, meaning low knowledge disclosure), strengthened IPR may discourage innovation overall. Walter G. Park and Ginarte (1997) have argued that countries in the transition from imitation to innovation should enhance IPR. This research provides more rational stages for catch-up countries to ideally enhance IPR.

The different contributions of IPR on the four aforementioned industries introduce new insight into the roles of IPR on innovation and economic growth. In the electronic industry, the empirical results suggest no relationship between strong IPR and R&D investment. With the presence of the ongoing debate on whether our IPR regime is providing the optimal environment for innovation, this result tempts us to rethink our current patent system. Also, the combined industrial analysis suggesting a greater direct effect of IPR makes us question the traditional role or IPR as an incentive mechanism of innovation. Perhaps our patent systems have gone “too far” in favoring patent holders, possibly discouraging follow-up innovations.

Finally, this research has also shown that the IPR in general, is a good mechanism for allowing a virtuous cycle of R&D and value-added factors. The effect of IPR appears in R&D activities, which then accumulates into the stock of R&D, therefore finally contributing to value-added industries. Besides these indirect effects, we have observed the direct effects of IPR on value-added factors, which can be explained by revenue effects from technological commercialization activities. By separating these two channels of effects, policymakers can distinguish between the roles of IPR in the short term and on long-term economic growth.

6.2 Limitations

The overall limitation of this research is that patent data was used from PCT-filed patents. In order to formulate an ideal level of patent propensity, we will have to gather patent data by technology from each national patents office. Thus far, PCT data is only available for such cross-country research. Also, in order to capture sequential innovation activities, ICT industries such as the software industry will be an appropriate start for studying the possible negative effects of IPR on sequential innovations. Thus far, we have no data on capital stocks or total labor hours in these industries. Shedding light on just R&D in these industries with the level of IPR may be possible in future research, given the existing limitations.

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Abstract (Korean)

본 연구의 목적은 지적재산권 제도가 혁신 활동 그리고 경제성장에 미치는 영향을 12개 국가에서 4개산업에서의 분석을 통해 밝히는 것이다. 또한 본 연구는 특허스톡과 연구개발스톡의 비율로 나타나는 특허성향 (Patent Propensity)이라는 새로운 개념을 정립하여 산업별 분석을 시도하였고 각 산업마다 고유한 특허성향이 어떻게 특정 산업의 지적재산권과 연구개발 활동의 관계에 영향을 주는지 살펴 보았다.

R&D 투자와 부가가치로 나타나는 연립방정식을 3SLS 추정방식으로 분석한 결과 특허성향이 높을수록 지재권의 연구개발에 미치는 영향이 높은 것으로 나타났다. 높은 특허성향은 특정산업에서 연구개발스톡 당 높은 특허스톡을 나타내고 이는 즉 더 높은 혁신역량을 의미할 수 있다. 지적재산권 제도가 인센티브 메커니즘으로서 연구개발활동에 영향을 주려면 수준 있는 혁신활동을 사전적으로 요구한다는 의미로 해석 할 수 있다. 또한 본 연구에서는 지적재산권 제도가 연구개발활동과 부가가치간의 선순환 구조에 기여한 다는 것을 볼 수 있었다. 지적재산권 제도로 인해 장려된 연구개발활동이 축적되어 결국 연구개발스톡의 형태로 산업 부가가치에 기여한다는 것을 볼 수 있었고 이는 즉 지적재산권이 연구개발활동을 장려함으로써 간접적으로 경제성장 (부가가치)에 기여한다고 볼 수 있었다. 동시에 지적재산권 제도가

직접적으로 산업 부가가치에 미치는 영향은 기술사업화 및 기술 라이센싱 활동으로 해석할 수 있었다.

산업간 실증분석을 통해 4개 산업의 특징을 도출 할 수 있었다. 지적재산권은 화학산업과 기계산업에서 유의한 설명변수로 나타났지만 전자통신산업에서 지적재산권은 연구개발활동에 아무런 영향을 주지 못했다. 현재 우리 특허제도가 과연 효율적인 동기부여 시스템을 제공하는지에 대한 논쟁은 주로 전자통신산업에서 과도하고 때로는 전략적인 특허경쟁에 초점을 두고 있으며, 본 연구의 실증분석 결과는 이러한 논쟁에 의미 있는 함의를 제공해 줄 수 있다고 생각한다. 산업 부가가치에 대한 지적재산권의 직접적 영향은 운송장비산업을 제외하고 모두 유의하게 나타났다. 이 중 지적재산권은 전자통신산업에서 가장 높은 기여도를 가진 것으로 나타났으며, 이와 같은 실증 결과는 전자통신 산업에서의 활발한 기술 사업화 및 라이센싱 활동을 반영했다고 볼 수 있다.

주요어: 지적재산권, 특허 성향, 연구개발투자, 산업 부가가치, 순차적 혁신, 기술 사업화
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