ANALYSIS OF THE FACTORS AFFECTING PCT PATENT APPLICATIONS : THE LANDSCAPE OF PATENT APPLICATIONS AND ITS IMPLICATIONS ON NATIONAL INNOVATION SYSTEM

By

CHO, Jihun

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ABSTRACT

ANALYSIS OF THE FACTORS AFFECTING PCT PATENT APPLICATIONS : THE LANDSCAPE OF PATENT APPLICATIONS AND ITS IMPLICATIONS ON NATIONAL INNOVATION SYSTEM

By

Jihun CHO

The purpose of this paper is to understand the mechanism of the patent system by identifying the factors affecting the number of PCT patent applications. The panel data regression in this study has confirmed that the amount of R&D expenditure is the single most critical factor affecting the number of PCT patent applications. The Pooled OLS, Fixed-Effect Panel regression and 2SLS unanimously showed that the coefficient for 'logged value of R&D expenditure' is around '1' which implies that the increase in the R&D expenditure leads to the same rate of increase in the number of PCT patent applications. In addition, the residual analysis indicated that even though South Korea is highest in R&D expenditure rate, it is lagging behind the US and Japan. The comparison of the National Innovation System between the US and South Korea suggested that in spite of the institutional and structural similarities, the operational inefficiency in the National Innovation System is responsible for the gap.

keywords: PCT patent application; the Pooled OLS, Fixed-Effect Panel regression and 2SLS; R&D expenditure; GDP per Capita; National Innovation System operational inefficiency

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I. Introduction

1. Statement of the problem

Innovations have become a critical determinant of competitiveness and economic growth, and the critical role of patents on innovation is widely acknowledged by many theoretical economists (Gilbert & Shapiro, 2006; Klemperer, 2006; Lerner, 2002). According to Guilbert & Shapiro (2006), the major function of the patent system is to provide incentives for the innovators. For the last 150 years, policymakers and theorists have always endeavoured to encourage innovations by identifying the most appropriate level of patent protection and optimizing the domestic patent policies (Lerner, 2002).

With the advancement of new technologies such as Information Communication Technology (ICT), nano- and biotechnology, the technological developments are not confined to individual nations, and the global concerns have shifted toward an increased level of international collaborations. As Melkers (2013) mentioned, "[The] science has evolved as an increasingly collaborative and global enterprise" (p. 389). It is not surprising that international efforts to harmonize different patent systems and to settle down Intellectual Property Right (IPR) related trade issues have become one of the most debated global issues (Mccalman, 2001)

In recognition of the significant role of the patent system, a wide range of studies have been carried out from the identification of the factors affecting patent applications and to prediction of the newly emerging technologies utilizing patent data (Daim et al., 2006; Miyamoto & Takeuchi, 2019). Patents have served as a useful tool in R&D project management by locating the competitive area based on patent data analysis (Miyamoto & Takeuchi, 2019). As the filing of a patent application is very costly, especially for the ones that are filed abroad, it is generally believed that the international patent applications are a reliable sign of significant technical changes and progress (Baglieri & Cesaroni, 2013).

Regarding the factors affecting patent applications, prior studies noted on the impact of GDP growth and R&D spending on the growth of patent applications in an effort to reveal the intervening causal relationships (Haber, 2016; Miyamoto & Takeuchi, 2019; Riel & Meiklejohn, n.d.; Sinha, 2008; Wang, 2013). In addition, most of the studies were conducted within the boundary of a particular nation.

For example, Sinha (2008) analyzed the correlation between GDP growth and the volume of patent applications in Japan and Korean. It did not take long before the narrow spectrum expanded to a multi-nation level, and the causal relationships began to be explored in the global context (Haber, 2016). Also, several studies took an interest in a specific topic such as global warming-related patents and its effect on economic growth (Miyamoto & Takeuchi, 2019).

However, most of the previous studies have been conducted based on national patent applications in the US, Europe, Japan and Korea, thus lacking international perspective. This study is intended to fill in the gap by providing a view of the patent landscape from the global perspectives. This study incorporates patent data from over 40 countries over the last decade. More significantly, this study contributes to the existing body of knowledge by testing the critical role of R&D investment in the recent explosion of the number of patent applications.

In addition, this study tries to provide ample implications for the individual countries' innovation system by identifying the most-efficient patent producing countries from the analysis of the residuals from the above panel data analysis. In this way, this study will explain the systematic reasons behind the difference in the efficiency of patent productivity.

2. Research question

In recognition of the critical role of the patent system on innovation, and the number of patent applications on economic growth, this study tries to investigate the following research questions :

- What are the factors that determine the number of PCT patent applications? To what extent do the identified factors affect the number of PCT patent applications?
- What is the current status of South Korea in terms of patent productivity? What are the differences in the National Innovation System between the most efficient patent producing countries and South Korea?

II. Literature Review

1. In General

Because of the increasing significance of the patent system, especially as a modern policy tool to promote innovation and to foster favourable environments for economic growth, there has been intense academic interests in understanding the nature of the patent system.

This tendency is well represented by the New Growth Theory, which thinks of knowledge as a new kind of input in the traditional growth model that is used to estimate the level of production. Relying on the theoretical framework of the New Growth Theory, this literature review is intended to provide a general view of the prior studies that were dedicated to the identification of the factors that affect the patent applications.

In the previous empirical studies reviewed in this study, the positive causal effects of R&D expenditure and GDP per capita as determinants of patent applications could be quickly confirmed, even though there exists a certain degree of differences in the strength of the causal relationships.

2. Theoretical framework

This study is conducted under the theoretical framework of New Growth Theory proposed by Paul M. Romer (1986), which emphasizes the critical role of innovation and knowledge in stimulating economic growth.

According to the traditional growth theory, which disregards the technological progress, the marginal return on investment is expected to diminish, reaching steady-state where no further per capita growth can be obtained. This is because, over a long period, the wage and capital-labour ratios across different countries converge (Ramsey, 1928).

However, under the New Growth Theory, knowledge causes an increasing marginal return because of the transformation of knowledge input to output. As knowledge accumulates, it will spill over the boundary of a firm, and the shared knowledge is used as an input to create new outputs. In this way, the creation of new knowledge by a firm plays as a positive external effect on the other firms (Romer, 1986).

The knowledge in the New Growth Theory can be any form of intangible assets like trade secrets, blueprints and design, but undoubtedly patent is one of the most promising form of knowledge that can be utilized to stimulate the economic growth.

Under this framework, it would be meaningful to understand the mechanism of the patent system by investigating the factors that affect its core operations and to elicit implications on how the patent information can be effectively used for the improvement in production.

3. Patent as a policy tool and an economic indicator

Innovations have become a critical determinant of competitiveness and economic growth, and the critical role of patents on innovation is widely acknowledged by many theoretical economists (Gilbert & Shapiro, 2006; Klemperer, 2006; Lerner, 2002). Especially, patent application is considered to be a useful indicator for measuring a country's level of technological development and the efficiency of scientific research (Lanjouw & Schankerman, 2004).

A patent is an intellectual property right for inventions that are granted to inventors or applicants by law for a limited period of time, in general, for 20 years. The patent holder is entitled to exclude others from exploiting the invention in exchange for the disclosure of the patented technical information.

According to Guilbert & Shapiro (2006), the major function of the patent system is to provide incentives for the innovators. For the last 150 years, policymakers and theorists constantly endeavoured to encourage innovations by identifying the most appropriate level of patent protection and optimizing the domestic patent policies (Lerner 2002).

For this reason, the patent counts, e.g. the number of patent applications or granted patents, are considered as a way of measuring innovation. However, measuring innovation through patents can be misleading, especially in making cross-national comparisons.

Firstly, the significance of patents is different depending on the individual country's economic and cultural environments. For example, some countries like Russia, do not prefer to make public the results of R&D. Secondly, some of the patents are very low quality to be considered representative of innovation activities. Thirdly, countries have different standards of patentability (Nagaoka et al., 2010).

In recognition of the significance of the patent system, a wide range of studies have been carried out from the identification of the factors affecting the patent system to the prediction of the newly emerging technologies utilizing patent data (Daim et al., 2006; Miyamoto & Takeuchi, 2019).

Recently, patents serve as a useful tool in R&D project management by locating the promising and competitive technical area based on patent data analysis (Miyamoto & Takeuchi, 2019). Also, as the filing of a patent application is costly, especially for the ones that are filed abroad, it is generally believed that the change in the number of international patent applications is a reliable sign indicating significant technical changes and progress (Baglieri & Cesaroni, 2013).

4. The Factors affecting patent applications

4.1 Overview

In recognition of the significance of the patent system, there has been a range of attempts to identify the factors affecting patent applications. Most of the prior studies noted on the impact of GDP growth and R&D spending on the number of patent applications and the possible causal relationships thereof (Haber, 2016; Miyamoto & Takeuchi, 2019; Riel & Meiklejohn, 2010; Sinha, 2008; Wang, 2013).

As can be seen in the empirical study of Sinha (2008), which investigated the correlation between GDP growth and the volume of patent applications in Japan and Korea, the earlier studies were mainly conducted at a national level.

However, it did not take long before the narrow national spectrum was extended to a multi-nation concern. The causal relationships began to be explored at an international perspective as can be seen in the study of Haber (2016). In addition, recent studies started to take an interest in a specific topic in a global context. For example, Miyamoto & Takeuchi (2019), launched a study on the global warming-related patents and their effect on economic growth.

4.2 Patent application and R&D expenditure

Contrary to the widely held belief that the number of patents is a clear indicator of research productivity, there has been scepticism over this optimistic view. It has been argued that patent applications are just the reflection of the propensity to apply for patent rather than the representation of actual innovation activities and expenditure on R&D (Rassenfosse & Potterie, 2009).

In dealing with this problem, Falk (2004), investigated the determinants of patent applications per capita based on the panel data from 22 OECD countries during the period 1980-1999. In the study, he discovered that R&D expenditure, especially in the private sector, has critical impacts on the number of patent applications with the estimated elasticity of 1.04.

The study also revealed that there are other variables that significantly affect the propensity of patent applications, such as the level of patent protection, and utilization of human capital etc. However, in the static model, which employs fixed effects estimator, only private sector R&D expenditure showed statistical significance (Falk, 2004).

The findings of Rassenfosse and Potterie (2009) well illustrate the close relationship between the volume of patent applications and the amount of R&D expenditure, which investigated the cause of the differences in the ratio of patent applications per researcher across different countries. Based on sample data from 34 countries, they found out that research productivity, which comes from R&D spending, thoroughly explains the cross-country variations.

4.3 Patent application and GDP/GDP per capita

There is also empirical study that examines the correlation between the number of patent applications and economic growth which is usually represented by GDP per capita. For example, in the study investigating the relationship between real GDP growth and the volume of patent applications in Japan and South Korea, Sinha (2008), found that the logarithms of real GDP are closely related to the number of patent applications, in some cases showing two-way causality.

Based on panel data analysis on Japan, Sinha (2008), argued that the relationship is one-way from GDP growth to the number of patent applications. However, regarding the reverse causal effect, i.e., the effect of patent applications on economic growth, the prior studies do not show consistency. In a study on nine Asian countries, Saini & Jain (2011), could find the direct causal relationship only in India and Philippines among nine Asian countries.

There are also many studies in this field conducted from the global perspective reflecting the general trend of the shift from national-level to international-level. Through cross-sectional data analysis on 23 countries, Ortiz-Villajos (2009), identified a strong long-term positive relationship between the number of patents and individual income. Similarly, Josheski & Koteski (2011), confirmed the long-term positive relationship between the growth of patent and GDP growth with slight time lags in G7 countries.

4.4 Other factors

Besides the above discussed two dominant variables, there are also various other factors that are considered to influence patent applications. As the study of Falk (2004) implies, the above mentioned variables such as the level of patent protection and the utilization of human capital can be promising candidates.

Similarly, Human Development Index (HDI) which was designed to measure the capabilities of people and the development of a country, and other auxiliary circumstances such as the cost for patenting could be counted as influential factors.

Nonetheless, it seems that the accumulated results of the prior studies only display a limited body of evidence for those additional variables, thus failing to provide a robust foundation.

5. Summary

To sum up, most prior studies confirmed the positive causal effect of R&D spending and GDP/GDP per capita on the number of patent applications. Accordingly, it could be a reasonable approach to construct the new prediction models around the above-mentioned two potential factors.

In the following section, the regression method will be employed to reveal the true causal relationship between various factors identified in this chapter and the independent variable, the number of PCT patent applications.

III. Results

1. In General

One of the aims of this study is to confirm the results of the prior studies with a different type of data set, i.e. the PCT patent application which is deemed to be the true proxy of global innovation activities.

In general, the number of patent application is used as a medium that represents the innovation activities because most of the significant research outcomes lead to patent applications. A considerable amount of domestic patents are just filed for defence purpose only without any intent to pursue economic incentives through loyalty revenue or any significant technical contributions to the existing technologies. For this reason, PCT patent applications, which involves a considerable amount of financial sacrifice, can truly represent an individual country's innovation-related efforts.

In this chapter, this study tries to confirm whether the R&D expenditure and GDP per capita, which were identified in the prior studies as the most critical factors affecting patent applications, also hold true in PCT patent application context.

2. Data Description

In this study, the panel data has been obtained from 40 countries around the world for the period between 2001-2018.

Dependent Variable

A large number of literature use the number of national patent applications as a measure for the innovation output (see, for example, Ernst, 2001; Sinha, 2008). However, as the national patents are issued in accordance with different patentability standards of individual countries, this approach shows a limitation in providing absolute measure. In addition, individual countries differ in their propensities to apply for patents (Maloney et al., 2003).

This study employs the number of PCT patent applications, that is filed through Patent Cooperation Treaty (PCT), to control for these differences, which are subject to similar patentability standards, examination procedures and costs as are described in PCT regulations. In addition, as the countries with less than 100 annual PCT applications showed very little consistency in their patenting activities over the periods, only the countries with the minimum meaningful level of PCT applications were selected as samples.

The PCT data can be easily retrieved from the World Intellectual Property Organisation (WIPO)'s website (Data for Researchers), which provides annual PCT application numbers by country and IPC technical classifications. In addition, The OECD Statistics (Triadic Patent Family Database) provides the number of PCT patent applications classified by nations and major technical fields.

Independent Variables

This study employs a wide range of independent variables that were frequently used in the prior studies as were reviewed in the literature review in the previous chapter. Even though there is no unversally accepted measure of inventive activities, the most commonly accepted determinants of a patent application is R&D spending and GDP per capita (Dearing, 2007; Falk, 2004; Ma & Lee, 2008).

As there is a strong correlation between R&D spending (RnD) and GDP per capita (GDPpc), this study employs new variable, R&D rate of GDP (RnDGDP), which denotes the ratio of R&D spending of GDP. The World Bank provides statistics on the GDP per capita, while UNESCO provides various R&D related statistics.

In addition, this study tests a range of covariates such as Human Development Index (HDI) from UNDP, Political Stability Index (pstab) from World Bank, the Number of Researchers per million (rsrchrmn) and Average Years of Education (eduyr) from UNESCO. Further, this study employs Subsidy Rate on R&D spending as an instrumental variable (IV) which can be obtained from OECD.

3. Methodology

This study is conducted primarily relying on quantitative analysis on the influence of R&D expenditure and GDP per capita on the number of PCT patent applications during the period from 2001 to 2018.

In an effort to test the influences of various factors, in this study panel, data regression method is conducted revealing the correlation between the dependent variable 'number of PCT patent applications (PCT)' and explanatory variables including GDP per capita (GDPpc), the amount of R&D investments, 'R&D rate of GDP (RnDGDP)' and other covariates such as Human Development Index (HDI), Political Stability Index (pstab), the Number of Researchers per million (rsrchrmn) and Average Years of Education (eduyr) from UNESCO.

In the first place, Pooled OLS regression is carried out to investigate the causal effects of covariates on the number of PCT patent applications. Then, the same regression is conducted using fixed effect panel regression in order to eliminate the unobserved time-invariant heterogeneities across different states. Finally, this study employs Subsidy Rate on R&D spending as an instrumental variable (IV) which can be obtained from OECD and applies the Two-stage Least Squares (2SLS) regression analysis.

Each of the methods offers advantages and disadvantages. The strategy of this study is to follow the method employed in the prior studies and compare the results to assess the validity or robustness of the findings of this study.

Empirical model

The estimation of the impact of R&D expenditures and other covariates are measured by the 'knowledge production function' or 'patent production function' suggested by Griliches (1979), which was followed by many innovation-related studies.

The function can be written in the general form as follows (Falk, 2004):

$$\ln y_{it} = \alpha \ln x_{it} + \beta z_{it} + \eta_t + u_i + \varepsilon_{it}, \text{ i=1 ...N and t=1...T} \quad (1)$$

where y_{it} is the output of knowledge production in state i in time t, x_{it} is research input and z_{it} is other variables affecting the output of knowledge production y_{it}. η_t is time-invariant characteristics, u_i is state-specific unobserved characteristics, and ε_{it} is idiosyncratic errors.

In this study, the knowledge production function is more specified using the number of PCT patent application as a substitute for the output of knowledge, and R&D spending and R&D spending ratio of GDP as a substitute for research input.

$$\ln PCT_{it} = \beta_0 + \beta_1 RnDGDP_{it} + \beta_2 \ln RnD_{it} + X_{it} + \alpha_s + \varepsilon_{it} \qquad (2)$$

where, $RnDGDP_{it}$ is R&D ratio of GDP, and ln RnD_{it} is R&D expenditure, and X_{it} is other covariates in state i in time t. α_s is unobservable fixed effect and is ε_{it} is idiosyncratic errors.

4. Results

In an effort to identify the relevant covariates, this study investigated the correlation among the candidate variables : lnPCT (log of PCT patent applications), lnRnD (log of R&D spending), RnDGDP (R&D spending ratio of GDP), lnGDPpc (log GDP per capita), eduyr (average years of education), pstab (political stability), RDsubsidy (R&D subsidy).

Table 1. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) lnPCT	1.000						
(2) lnRnD	0.891*	1.000					
(3) RnDGDP	0.575*	0.406*	1.000				
(4) lnGDPpc	0.286*	0.127*	0.529*	1.000			
(5) eduyr	0.424*	0.290*	0.648*	0.705*	1.000		
(6) pstab	0.046	-0.196*	0.182*	0.627*	0.577*	1.000	
(7) R&DSubsidy	-0.057	-0.021	-0.209*	0.067	-0.324*	-0.010	1.000

* shows significance at the 0.01 level

The investigation showed a significant level of correlation between the number of PCT patents and R&D expenditures, GDP per capita and average years of education while indicating very little correlation with R&D Subsidy.

Other related variables such as HDI (Human Development Index), OECD (the status of

OECD membership), the number of researchers, *etc.* showed a very close correlation with the average years of educations. As these variables acted in the same way showing redundancy, only eduyr (the average year of education) was selected as the representative variable covering all those variables.

4.1 Pooled OLS regression

As can be seen in below Table 2. the pooled OLS regression shows that lnRnD (R&D spending) and RnDGDP(R&D spending ratio of GDP) are statistically significant with the coefficient of lnRnD around 1, and the RnDGDP (R&D ratio of GDP) around 0.4. The obtained coefficients suggest that the increase of R&D expenditure and R&D ratio of GDP by 100% result in the increase in the number of PCT patent applications by 100% and 40% respectively.

In spite of the prior studies claiming the close causal relationship between GDP growth and the increase in the volume of patent applications, those relationships were weak. However, as was noted in Falk (2004) and Hu & Png (2010), the GDP growth inevitably leads to the rise in the R&D expenditures. Accordingly, it would be reasonable to assume positive correlation between the number of patent applications and GDP.

The average years of education (eduyr) was also statistically significant in determining the number of patent applications. The coefficient was around 0.1, which indicates that the average years of education account for a 10% increase of PCT patent applications.

4.2 Fixed Effect (FE) Panel regression

In the analysis of panel data, where longitudinal observation is possible, it is allowed to control for unobservable variables like entity-specific characteristics. Also, time-invariant characteristics can be eliminated by subtracting the time mean (Wooldridge 2016).

In the above equation (1), u_i is state-specific unobserved characteristics which can be eliminated by employing fixed-effect model. In this way, year and country (state) specific effects, which may influence the Pooled OLS regression, can be controlled for.

The fixed model (FE) regression, indicated that only the dependent variable lnRnD is statistically significant with the coefficient value of 1.06. The identified coefficient value is consistent with the findings in the Pooled OLS regression. However, the fixed model shows that there is very little correlation with the GDP related variables.

4.3 Two-Stage Least Square (2SLS) regression

In general, Randomized Control Trials (RCT) is considered to be the ideal way because it allows for the elimination of various sources of biases. However, in many cases, the application of RCT is not appropriate because of time and cost restrictions. Further, in many cases, dependent variables affecting the dependent variable are omitted resulting in endogeneity problems (Wooldridge 2016).

At present, one of the prevailing methods for resolving the omitted variable bias is to utilize an instrumental variable (IV) that is related to the independent variable but does not have a direct correlation with the dependent variable.

In this study, we tested the RDSubsidy (R&D Subsidy) as an IV that does not correlate with the dependent variable, lnPCT, but influences the dependent variable via dependent variable lnRnDGDP.

The 1st stage and 2nd stage equations are as follow :

- 1st stage : $RnDGDP_{it} = \pi_0 + \pi_1\ RDSubsidy_{it} + \pi_2\ Log(RnD)_{it} + \pi_3\ eduyr_{it} + \delta_s + \upsilon_{it}$ (3)
- 2nd stage : $Log(PCT)_{it} = \beta_0 + \beta_1\ RDSubsidy_{it} + \beta_2\ Log(RnD)_{it} + \theta_s + \eta_{it}$ (4)

As was seen in Table 1., the independent variable RDSubsidy (R&D Subsidy) has no direct correlation with dependent variable ln PCT (number of PCT patent applications), but a little correlation with RnDGDP, which implies that RDSubsidy affects lnPCT by way of dependent variable RnDGDP.

As can be seen in below Table 2. 2SLS regression, which employs R&D subsidy as an instrumental variable, also showed similar results with above Pooled OLS and Fixed effect regressions. The coefficient from 2SLS regression was 0.998, which is consistent with the results of the above regressions.

4.4 Summary

In this chapter, we applied three types of different regressions, i.e. pooled OLS, fixed effect model, 2SLS regression, in an effort to estimate the correlation between the number of PCT applications.

All the above regression models indicated that R&D spending is critical in producing PCT patent applications. Also, it was found that the above results are consistent with the finds of the prior literatures. For example, in Maloney (2003), which was conducted based on US granted patents, the coefficient of ln R&D showed 1.01. In WIFO working papers authored by M. Falk (2004), which was conducted based on the EPO patents from OECD countries, found that the long-run elasticity for business enterprise R&D expenditures has a long-term elasticity of 1.04.

Similarly, in TÜREDİ (2016), which investigated the relationship between R&D expenditure and the number of patent applications in 23 OECD countries, the coefficient for lnRnDGDP was 0.4, that is 1% increases in the share of R&D spending contributed to the increase in the number of patent application by 0.4%.

However, as for the GDP or GDP per capita, it was not found to have any close correlation with the increase in the number of PCT patent applications. This result is slightly annoying because in general, the GDP and R&D spending tends to move in the same direction even if they do not change at the same rate.

To sum up, this study could confirm that the R&D spending is the single most critical factor that affects the number of PCT patents, and the increase rate in R&D spending is proportional to the growth in the number of PCT patents.

Table 2. Results of Regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pooled OLS					FE	2SLS
lnRnD	1.151***	1.017***	1.022***	1.003***	0.978***	1.060***	0.998***
	(0.025)	(0.023)	(0.023)	(0.034)	(0.036)	(0.098)	(0.042)
RnDGDP		0.494***	0.451***	0.349***	0.328***	-0.026	0.043
		(0.034)	(0.040)	(0.059)	(0.060)	(0.093)	(0.278)
lnGDPpc			0.091**	0.027	0.091	0.074	0.229
			(0.044)	(0.079)	(0.087)	(0.107)	(0.170)
eduyr				0.099***	0.119***	-0.026	0.187**
				(0.030)	(0.032)	(0.040)	(0.074)
pstab					-0.132*	-0.146*	-0.229**
					(0.076)	(0.086)	(0.109)
_cons	-4.341***	-3.999***	-4.886***	-5.113***	-5.653***	-3.900***	-7.416***
	(0.237)	(0.203)	(0.477)	(0.698)	(0.763)	(0.997)	(1.974)
Obs.	557	557	557	305	305	305	291
R-squared	0.794	0.850	0.852	0.833	0.834	.z	0.822
year	No	No	No	No	No	Yes	No
country	No	No	No	No	No	Yes	No

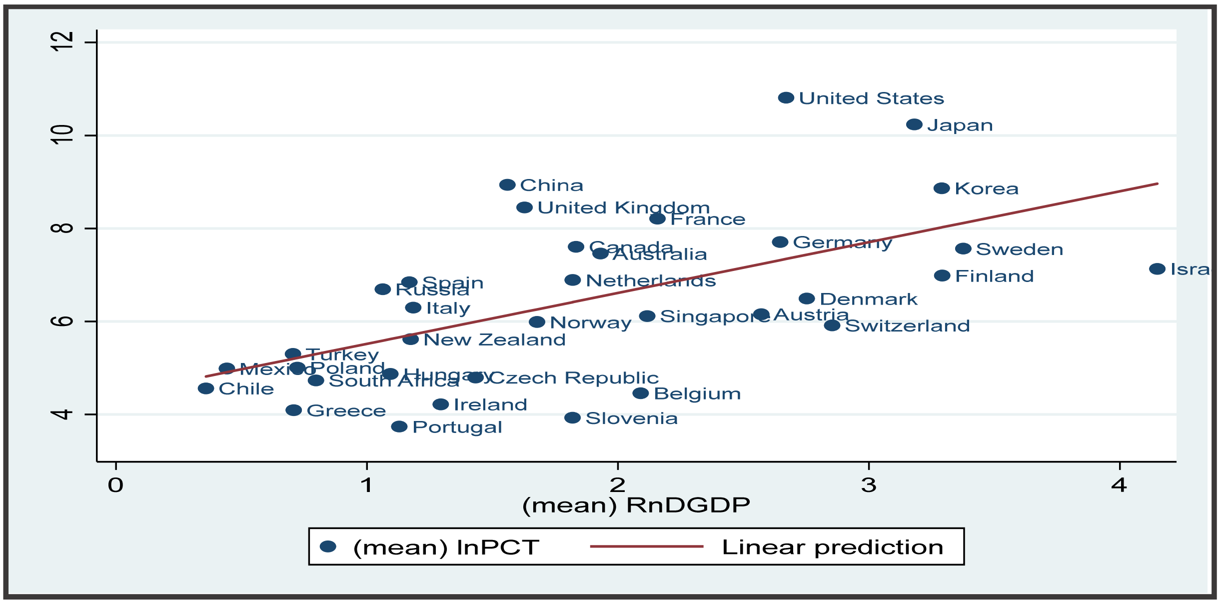
****** p<0.01, ** p<0.05, * p<0.1***

5. Residual Analysis

In the previous section, this study examined the correlation between the number of PCT patent applications and R&D spending. In this section, this study investigates each country's own position in the relationship between PCT patent applications and R&D spending. In this way, the most efficient patent producing countries and the least efficient countries can be identified.

For this, we calculated the residuals, which are the differences between the fitted value and the real value of individual countries. The residuals can be easily estimated by using the 'predict' command in STATA with the same panel data, which was uses in previous regressions.

Figure. 1 lnPCT – R&D/GDP Chart

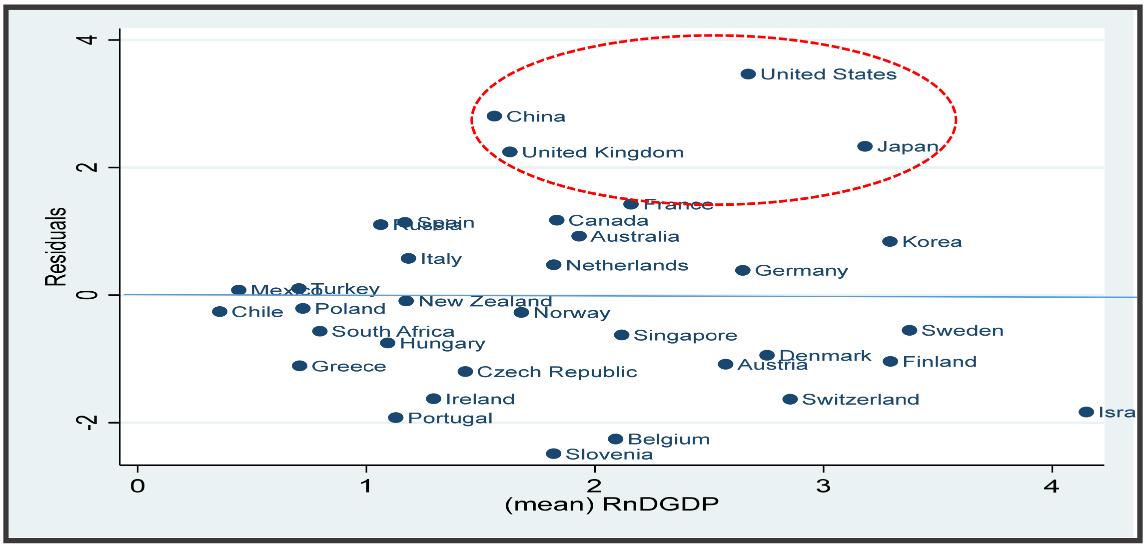


In Fig 1., each dot represents the individual countries, and the straight line indicates the fitted OLS regression line. The x-axis is the mean value of R&D/GDP, and the y-axis is the value of ln PCT.

According to the chart, the United States, Japan, China, the United Kingdom (UK) and Korea are the countries with the highest level of PCT patent applications. In the ratio of R&D spending of GDP, Israel is by far the most dedicated R&D spending countries followed by countries like US, Japan, Korea, Sweden and Finland.

The residuals can be more clearly identified by putting the values of residuals on the y-axis, as can be seen in below Fig. 2.

Figure. 2. Residual – R&D/GDP Chart



The countries above the straight horizontal straight line, *i.e.*, the United States, China, the UK, Japan *etc.* indicate that their R&D spending ratio is above the average level of the sample countries. To the contrary, the countries below the horizontal line mean that their tendency of R&D spending is lower. Thus, it can be said that the countries above the horizontal line are more innovation-oriented countries.

IV. PCT Patent Applications and the National Innovation System

This chapter evaluates the current Korean national innovation system based on the findings in the previous chapter. In the last chapter, it was found that the US, Japan, the United Kingdom and China along with South Korea are the most efficient countries in terms of patent productivity out of unit R&D spending. However, it was also noted that, even though South Korea belongs to the leading group, still it fell behind of the US, Japan, UK and even China in spite of its highest level of R&D spending ratio. What makes such a difference within the leading group, and how can the South Korean national innovation system be improved in a way to ensure operational efficiency, especially in terms of patent productivity?

In this chapter, we analyze the strengths and weaknesses of the Korean innovation system in comparison with other most efficient countries, especially the US, in search of policy implications for further improvements. There can be various approaches to deal with the innovation-related matters, but in this chapter, the focus is only put on the patent-related perspective.

1. The Nature of National Innovation System

Freeman (1987), defined a national innovation system as the network of public and private institutions which creates a flow of new technologies. Similarly, Lundvall (2002), defined it as the interaction in the production and usage of new knowledge.

From, the above definitions, it can be noted that innovation is related to ‘knowledge’ and ‘interaction’. As OECD mentioned, innovation is the products of instant interaction among various actors in the system, where the innovation is achieved through constant feedbacks in the system (OECD 1997).

In addition, many studies on national innovation system have paid particular attention to the ‘flow of knowledge’. As a matter of facts, knowledge is widely acknowledged as the primary driving force of modern economic development and its critical role is further growing as the modern economic activities are becoming more knowledge-based (OECD 1996).

Accordingly, it can be argued that the essence of the success of national innovation system lies in the efficiency of sharing technological information among entities or actors in the system (OECD 1997). Thus, the relationships or the interactions among the actors are connected by way of ‘flow of technology and information’ which determines effective sharing and diffusion of technological knowledge in a system.

Considering the characteristics of national innovation system, the measurement and assessment of national innovation system can be conducted from three perspectives : 1) technical collaboration with other companies, universities, and other technical collaboration, 2) diffusion of technology and information, and 3) personnel mobility between public and private sectors (OECD 1997).

As the ‘flow of knowledge’ is affected by various environmental factors and interactions among entities in a system, the efficiency of the national innovation system is different across countries. According to Mahlich and Pascha (2012), innovation systems are embedded in the econoy, society and culture, where the ‘cultural context’ plays a most critical role in formulating the innovation system.

According to Lalkaka (2002), the national innovation system is a mixture of technology policy, innovation strategy, human resources, technical support, mobilization of financial resources and international cooperation.

Among the above sub-systems, the following sections mainly focus on patent-related aspects and tries to examine various aspects of the national innovation system that affects the efficiency thereof.

2. The National Innovation System in the US

2.1 In General

The US innovation system can be characterized by its size, diversity, high level of R&D spending for basic research and strong commercial orientation (Shapira & Youtie, 2010). The US national innovation system is composed of diverse entities involving the federal government, state government, public agencies, universities, and private companies.

The US federal government provides necessary infrastructure and framework such as financial market regulation and intellectual property system etc. According to the US National Science Board statistics (2018), the federal governments provide 60% of funding for academic R&D. In addition, the portion of academic R&D spending on basic research amounts to as much as 63%.

Table 3. Education R&D expenditures in the US (2012-2016)

(Thousands of dollars)

Year	Type	All sources			Federal sources		
		Total	Basic	Applied	Total	Basic	Applied
2012	All institutions	65,729,007	42,401,697	17,295,653	40,142,223	26,469,347	10,577,754
	Public	44,162,595	28,763,003	11,666,386	25,109,740	16,571,834	6,654,107
	Private	21,566,412	13,638,694	5,629,267	15,032,483	9,897,513	3,923,647
2013	All institutions	67,013,138	43,305,409	17,390,865	39,445,931	26,071,617	10,327,219
	Public	44,849,697	28,878,632	11,910,906	24,688,555	16,200,772	6,615,036
	Private	22,163,441	14,426,777	5,479,959	14,757,376	9,870,845	3,712,183
2014	All institutions	67,196,537	42,989,478	17,745,860	37,960,175	24,905,121	10,015,778
	Public	44,675,392	28,553,622	11,848,740	23,496,472	15,330,179	6,199,866
	Private	22,521,145	14,435,856	5,897,120	14,463,703	9,574,942	3,815,912
2015	All institutions	68,566,890	43,865,982	18,022,569	37,848,552	24,945,232	9,969,994
	Public	45,428,567	28,984,600	12,036,229	23,389,238	15,368,215	6,183,940
	Private	23,138,323	14,881,382	5,986,340	14,459,314	9,577,017	3,786,054
2016	All institutions	71,833,308	45,101,655	19,986,766	38,793,542	24,944,577	10,893,286
	Public	47,147,814	29,778,373	12,961,231	23,947,624	15,394,204	6,709,633
	Private	24,685,494	15,323,282	7,025,535	14,845,918	9,550,373	4,183,653

Source(s): The US National Science Foundation Statistics.

In the US innovation system, diverse entities are involved in establishing a national innovation policy. For example, the National Science Foundation (NSF) is responsible for providing innovation-related statistics and measurement and analysis of the national innovation status. The National Science Foundation (NSF) operate the Industry-University Cooperative Research Centers (IIUCRC) and the Engineering Research Centers.

The US Congress has responsibilities for introducing legislation for promoting innovation activities along with holding hearings and testimonies from various stakeholders. Also, there are a number of intermediary organizations that plays a critical role in national innovation policymaking. In general, the US legal and regulatory framework is predisposed towards encouraging entrepreneurs to innovate and to take risks (Shapira & Youtie, 2010).

2.2 The State's Role in the National Innovation System

As Keynes noted in *The End of Laissez Faire (1926)*, the role of government is to do tasks that cannot be easily undertaken by the individuals or private companies but do things that are not done at all. This Keynesian idea of discrete government's role seems to be well reflected in the US national innovation system.

It is widely acknowledged that the US has been the global symbol of innovation as is represented by Silicon Valley. In the US innovation model, the public research sector is the most important source of knowledge (OECD 1997). As Mazzucato (2013), argued in her book 'the entrepreneurial state', the State-funded researches have brought about cutting-edge new technologies.

For example, the US government made massive investments in the early-stage research of new technologies such as the Internet, biotechnology and shale gas, where most private companies were reluctant to take risks because of the uncertainties of the commercial success. It was only after the fundamental researches on new technologies have been accomplished that the knowledge-sharing within the entities in the national innovation system took place for commercial opportunities. The US government was generous in allowing private companies to join and take advantage of the developed technologies along the way (Mazzucato, 2013).

2.3 Patent system, innovation and diffusion of knowledge

The patent system played a unique role in promoting the development of new technologies and the diffusion of technical knowledge in the US national innovation system. Historically, there have been continuous debates on whether strengthened patent protection leads to technological advances and the promotion of innovations.

Some thought that the monopoly granted by patent right usually sets back innovation rather than promote it. However, as were demonstrated in many empirical pieces of evidence, the innovation is mostly driven by the expectation of profiting from the patent right (Woo et al., 2015). For this reason, many countries are trying to foster their patent system in an effort not to be left behind in the age of global competition.

In the USPTO Strategic Plan 2018-2022, the US Patent Office (USPTO) has established three strategic goals of : 1) high patent quality and timeliness, 2) high trademark quality and timeliness, and 3) domestic and global leadership in enforcing global IP protection.

The first and second goal is about the original function of Patent Offices, which is to promote innovation by proper delivery of high-quality patents in a timely manner. For example, the US Patent Office (USPTO) set up several objectives in the aim of achieving the strategic goal : 1) optimizing pending period, 2) ensuring high quality, 3) fostering innovation, and 4) improving the patent trial system (Patent & Office, 2018).

From the listed objectives, it can be easily noted that most of the objectives are the ones that are commonly pursued in every Patent Offices around the world, and it seems that there is nothing unusual or unexpected in themselves.

However, the third goal is somewhat peculiar in that it is intended for the global management of Intellectual Property Right (IPR) policy, i.e. the enforcement and protection worldwide to ensure the interests of the US companies. The strategic use of IP policy is facilitated by the dominant US economic and political power. For example, the Office of the US Trade Representative (USTR) frequently comes up with IPR issues in trade negotiations identifying the countries that deny adequate IPR protection for US companies (Patent & Office, 2018).

2.4. Patent policy and innovation

In the early 1900s living organisms were not eligible patentable subject matter not only in the US territory but also globally. In other words, the invention on living organisms such as livestock, micro-organisms and plants could not be granted patents. However, after the World War I, the increasing concerns for food security prompted the extension of the scope of patentable subject matter to include the plants that propagate asexually (*see* US Plant Patent Act 1930).

By enforcing a patent right for plants, the US government could encourage innovation in the plant breeding industry. For example, a new breed of rose could be easily copied by competitors through an easy and simple procedure of cutting the stalk of rose and inserting it in the soil. However, with the legal protection banning the unauthorized copy of new breeds, the US rose industry, which initially had depended on European rose breeds, slowly developed their own breeds (Moser, 2013).

In the field of chemicals, keeping secret of the developed technical information was the most preferred way of protecting the precious knowledge assets in the mid-1900s. However, after the development of reverse engineering technology, which is a scientific tool to analyze the ingredients of chemicals, the demand for patent protection as a most reliable tool for legal protection has increased significantly (Moser, 2013).

With the emergence of the Internet and computer technologies, new forms of technologies, i.e. e-commerce and software, began to be patented. In 1998, patents were granted to business methods with the decision of United State Court of Appeals in *State Street Bank & Signature Financial Group, Inc. (47 USPQ 2d 1596, CAFC 1998),* which is about a method of operating financial businesses on the Internet. Traditionally, an idea or concept was not accepted as eligible for patent protection, but the US government was flexible and progressive enough to recognize and realize the industry's needs. In 1981, the US Supreme Court decided in *Diamond v. Diehr (450 U.S. 175, 1981)* that anything that is made by man is a patentable subject matter.

Similarly, the US court's pro-patent attitude can be found in biotech patents such as genetic sequences (DNA). The US courts, which were very sensitive to the needs of the industry, allowed patenting on synthesized genetic sequences. In an amicus brief to the court relating *Myriad* case, a group argued that granting patents on genes is critical for the US biotech industry to attract necessary capital investment for the development of innovative technologies.

Still, there are much criticisms on patenting genes for various reasons : a) genes are products of nature, b) monopolization of genes may hinder research and limits patient's access to cure, etc. However, it is undeniable that gene patents have contributed to promoting innovations in the field by attracting a huge amount of investments, and at the moment, most of the global leading biotech-companies originated from the US laboratories.

In *Myriad* case (2009), medical societies, researchers and patients have sued Myriad, which obtained patents on two genes, BRCA1 and BRCA2, which are related to breast cancer. Myriad commercialized the genes in providing breast cancer test for more than $3,000. However, the US Supreme Court finally confirmed the validity of the patents admitting that “even though naturally occurring genes are not patentable, the cDNA or synthetic DNA is eligible for patent protection because it does not exist in nature or occur naturally.”

In this part, we investigated how the US government and the US courts have reacted to the needs of the national industries facilitating the use and commercialization of new technologies. In fact, the measurement of the effect of the change in patent policy on a patentable subject matter is not simple because it involves too many causal relationships between various factors which sometimes seems contradictory. However, it appears that at least one thing is certain : the legislative or national policy supports help to get rid of uncertainties concerning huge investments in unproven new technologies and to facilitate innovations by encouraging capital investments.

2.5. Legislative support

In the first place, the results of public research remained in the public domain so that they can be accessed by any members in the society considering the public good nature of the research. However, the US Bayh-Dole Act (1980) allowed private ownership of the patent right over the results of the publicly-funded research and the right to offer licenses to private companies.

As a result, the private companies could benefit from the public R&D by commercializing the newly developed technologies which, otherwise, would have been put to sleep in the laboratory documents.

At the same year, the Stevenson-Wydler Technology Innovation Act (1980) was introduced, which enables the federal laboratories to transfer developed technology to industry. In the aftermath of the Bayh-Dole Act (1980) and the Stevenson-Wydler Technology Innovation Act (1980), many universities established technology transfer offices (TTO) to conduct the role of licensing and commercialization of the R&D results.

In the late 1960s, the US universities obtained only 200 patents annually, and in 1980s the number increased to around 500. However, after the Bayh-Dole Act (1980), the number of granted patent exploded to 3,000 annually. The Bayh-Dole Act was recognized as the driver for rapid increase in the patenting activities in the US universities. The emergence of the biotechnology industry since the late 1990s is also thought to be an excellent example of the positive effect of this legislative support. For this reason, it is not strange that most of the currently influential biotech companies were spinoffs from the U.S. university laboratories (Mowery, David & Ziedonis, 2002).

2.6 Summary

The US innovation system has well-organized and diversified knowledge sharing and cooperation structure among the federal government, local government, various agents and private companies. The public sector makes initial stage investment in the basic research that would prompt future commercial applications, and the R&D result is efficiently shared among private companies in the form of licensing.

In addition, the US innovation system is well sustained by institutional supports. The US courts have paved the foundation for incorporating new technologies into the existing patent system by providing legal justification. The US government sets up general directions for the technological developments and establishes policies that would facilitate the transfer and diffusion of R&D results. The public agencies or institutions fund the R&D on new technologies, and support the commercialization of the developed new technologies by licensing. And the private companies are eager to take risks for the commercialization of the licensed new technologies.

It seems that the well-organized innovation structure and well-defined role shared among actors in the US innovation system not only promotes the innovation itself but also makes the commercial value of patent worth more.

3. Innovation System of South Korea

3.1 In general

South Korea has achieved unprecedented economic miracle mainly supported by the leading role of prudent government, especially in establishing effective industrialization policies and pouring high levels of investment in human capital (Kim, 1991). In the 1950s, South Korea was one of the most destitute countries in the world, but at the moment South Korea is ranked world 11^{th} largest economy.

The early-stage industrialization process was conducted with the mobilization of human and capital resources combined with the high technologies from foreign countries. As South Korea is short of natural resources, the national development strategy had to rely on human capital with the government making massive investments in education.

The other characteristic of Korea's innovation system in the early stage is the heavy dependence on the manufacturing sector and big conglomerates' critical role in boosting the industrial revolution since the 1960s. In the early stage, rapid industrialization was made possible by relying on cheap labour cost and high-quality human resource combined with strategic governance.

However, as the industrialization process accelerates, the strategy of 'cheap labour cost combined with imported technology' did not work well. Instead, technical innovation for cutting-edge technology has become most important for South Korean companies to remain competitive in the global market (IDA, 2013).

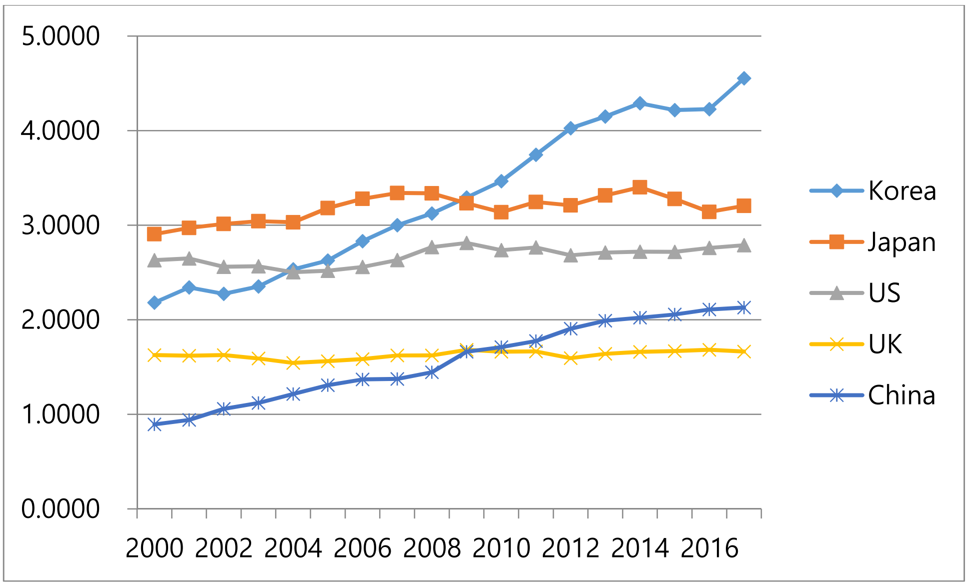
The South Korean government's plans for science & technology innovation in the 1990s and 2000s was established to improve capacity for R&D, developing R&D workforce and increasing fund for basic science, which resulted in enhanced R&D intensity and patent applications. The national R&D intensity has risen to a level of 3% since 1990, which is one of the highest in the world (Mahlich & Pascha, 2007).

As the size of the economy expands, the private companies began to hold the initiatives for the development of cutting-edge forefront innovations. At the moment, most of the cutting-edge innovations are undertaken by major conglomerates companies like Samsung, Hyundai and LG *etc.*

3.2 R&D investment and PCT patent applications

The chart below illustrates the trends in R&D expenditure as a share of GDP in the countries which showed the most efficient patent productivity in the previous chapter. According to the chart, the R&D spending ratio of South Korea is highest among the leading countries, showing a steady increase.

Figure 3. R&D Expenditure of GDP rate (%) (2000-2017)



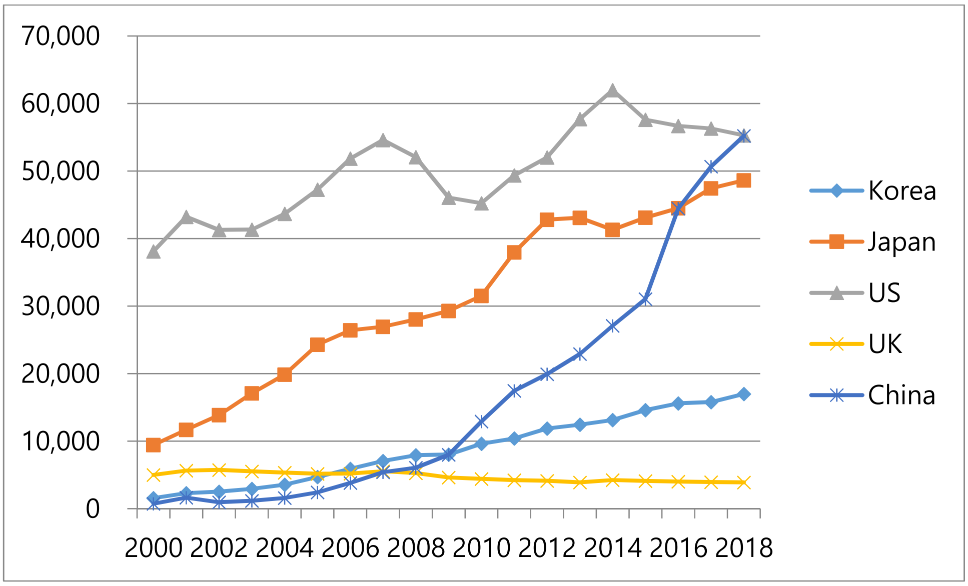
Source(s) : OECD statistics on R&D expenditure

However, in terms of the number of PCT applications, as can be noted in the below chart, other countries far outnumber South Korea. Also, in terms of the increase rate, South Korea is outnumbered by China in spite of slight prevalence over other countries.

As for the general structure of the Korean National Innovation System, it is generally believed that the system is benchmarked from the US innovation system (Shipp & Healey, 2013). For this reason, it is not surprising that the South Korean innovation system resembles the US innovation system not only in the organization and funding structure but also in policy and decision-making procedures.

In addition, the national patent law and patent examination guidelines have been under continuous revision reflecting the recent changes in the US patent system. At the moment, the patentability standards around the world are very similar except for some minor procedural details.

Figure 4. Number of PCT applications (2000-2018)



Source(s) : WIPO statistics on PCT applications

3.3 Knowledge Diffusion and Technology Transfer

Since the 1990s, the Korean government-supported technology transfer and knowledge diffusion mainly by increasing the number of publications on technology and the number of patents. At the moment, South Korean is the world's 4th largest patent applying country accumulating an enormous amount of technology-related documents. However, the level of technology transfer from universities or public institutions to private companies is quite low in comparison with other competing countries.

According to a report to Korea Science related Minister Conference (2019. Jan 8), it is recognized that the number of technology transfer is minimal while the number of average patent applications is as much as 15 times for universities, and 7 times for public institutions in comparison with universities in other countries. As can be seen in the table below, the technology transfer and licensing performance are extremely low, considering the high level of patent applications from public institutions.

Table 4. Technology Transfer and Licensing (2000-2017)

	2011	2012	2013	2014	2015	2016	2017
Transfer(paid)	330	383	538	718	1,107	1,587	1,466
Transfer(free)	-	-	-	419	550	511	282
Licensing(paid)	2,759	3,557	3,457	4,098	5,113	5,385	4,905
Licensing(free)	178	282	263	639	322	327	278
Option contract	5	0	1	0	0	1	0
OEM etc	148	90	99	107	207	226	546
Sum	3,420	4,312	4,358	5,981	7,299	8,037	7,477

Source(s) : Korea Institute of Intellectual Property statistics

Above statistics insinuates that there is very little chance of knowledge transfer from domestic public domain to private sector.

Inspired by the US Bayh-Dole Act (1980), legislations such as Technology transfer and commercialization promotion Act (2002), and Industrial Education Enhancement and Industry-Academia Research Cooperation Promotion Act (2003) followed in an effort to ensure and facilitate the technology transfer from the public sector to private companies. In addition, the South Korean government encouraged universities to establish technology transfer offices (TTO). However, still, there seem to be any noticeable improvements.

It is often criticized that in selecting the R&D subject, the needs from the private sector are ignored. However, the real culprit lies in the operational inefficiency of the TTO. According to Mowery & Sampat (2005), without 'rooted efforts to engage in collaboration with the private sector and to transfer technologies', the perfunctory imitation of the US Bayh-Dole policy would not work. In South Korea, in spite of the strong drive from the government, it is challenging to formulate autonomous cooperation with the private sector. In addition, the operational inefficiency resulting from lack of expertise and experience of the TTO aggravates the situation (Han, 2018).

4. Analysis

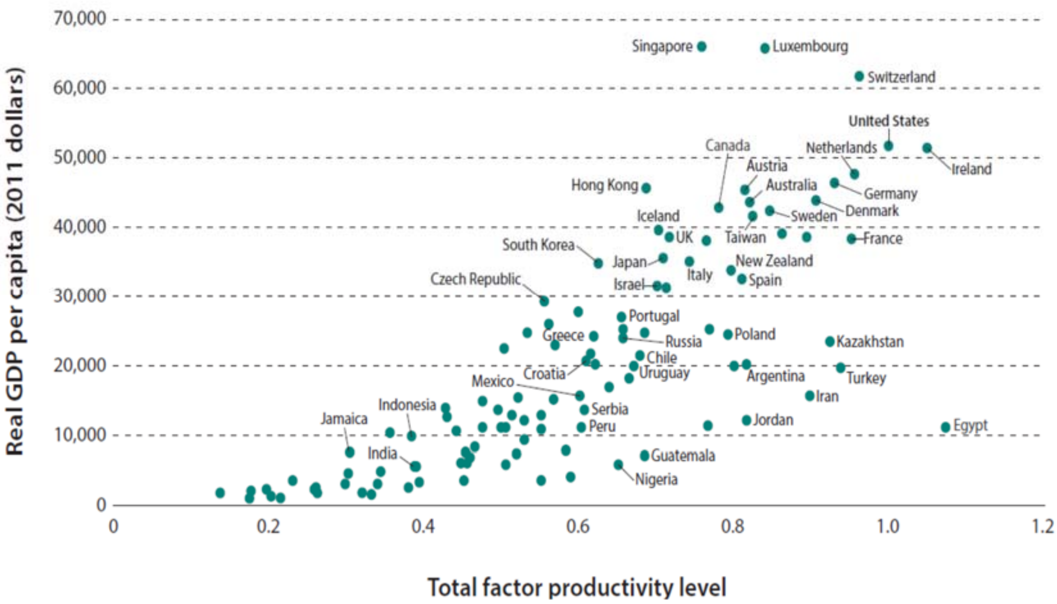
4.1 Innovation, Total Factor Productivity (TFP) and reform in the patent system

In general, the differences in incomes across countries cannot be easily explained by the differences in the inputted capital and labour because of the differences in productivity. In growth accounting, the Total Factor Productivity (TFP) denotes the measure of the effectiveness of an economy in producing output with a given amount of inputs (Shambaugh et al., 2017).

In a similar way, the patent productivity in this study can be defined as the measure of the effectiveness of an economy in producing patents with a given amount of R&D expenditure. The TFP and patent productivity have in common in that both of them refer to the efficiency in the innovation pipeline.

According to the Hamilton project (2017), countries like the US, and Germany show high TFP indicating that they utilize the labour and capital in a more efficient way. Thus, it is not surprising that the countries with high TFP coincide with the countries that show a high level of patent productivity of R&D spending illustrated in the previous chapter.

Figure 5. Total Factor Productivity and Real GDP per Capita in 2014, by Economy



Source(s) : Hamilton Project, Brookings report (2017)

The implication of the analogy of TFP and patent productivity is that the patent system should be streamlined to eliminate inefficiencies and stimulate innovation. The patent system should be designed in a way to accommodate the balance in the costs and benefits. While patents secure legal protection on the innovation, it also limits competition by allowing monopoly by the patent holder., the patent system should be optimized considering these innate characteristic as well as the innovation boosting quality of patent protection.

4.2 Efficiency in the National Innovation System

As examined in the previous section, there seems to be very little difference in the institutional structure of National Innovation System between the US and South Korea, and it is just a matter of how effectively the innovation system is operated and managed.

From the practical perspective, it may be argued that the efficiency of the National Innovation System should be evaluated by the amount of commercialization of the R&D results. In this viewpoint, South Korea is considered to be lacking good efficiency because, in spite of a large volume of annual domestic patent applications, the cases of technology transfer and resulting commercialization is relatively small.

In addition, as for the difference in the patent productivity with other leading countries, it can be partly explained by the small amount of budget provided for international patent application. According to a report on Korea Science related Minister Conference (2019. 8. Jan), even the Electrics and Telecommunications Research Institute (ETRI) which ranks 1st in loyalty revenue in South Korea, is suffering from lack of budget for patenting abroad. The shortage of budget explains why the ratio of PCT applications, which cost far more than domestic patent applications, is less than that of other countries.

From the above explanation, it may be argued that if we consider the total number of domestic and international patent applications altogether, we may have somewhat different results. However, considering the fact that only valuable technologies are applied for international patent applications such as PCT application, the statistics based on PCT may correctly reflect the efficiency of the National Innovation System of South Korea.

In the meantime, the patent productivity analysis in the previous section showed that China is very efficient, implying high efficiency in the National Innovation System. However, it seems that China is also experiencing a similar or even worse situation than its' neighbourhood.

China has shown a dramatic increase in the number of patent applications and since 2011. China surpassed the US and Japan, recording the world number one country in the number of the patent application. However, it was reported that the rapid increase in the volume of patent application in China is mainly due to the Chinese government's patent promotion policies (PPPs) that links tax incentives and subsidies with patenting. Also, it is also noted that the rapid growth in the quantity has resulted in deteriorating patent quality (Long & Wang, 2019).

To sum up, under the South Korean context, the most urgent challenge to National Innovation System is to strengthen knowledge diffusion and technology transfer for the enhancement of the efficiency of the innovation ecosystem. In addition, more practicality-oriented innovation policies that connect the funding for R&D with the commercial applications of the result seems to be required.

V. Conclusion

The panel data regression in this study has confirmed that the amount of R&D expenditure is the most critical factor affecting the number of PCT patent applications : the Pooled OLS, Fixed-Effect Panel regression and 2SLS unanimously showed that the coefficient for ‘logged value of R&D expenditure’ is around ‘1’ which implies that the increase in the R&D expenditure leads to the same rate of increase in the number of PCT patent applications.

The result of this study is in line with the prior studies, which utilizes the data on the national level patent applications. However, the effect of GDP per capita, which was shown in the prior studies to have a significant effect on the number of patent applications, was inconsistent. While earlier studies showed the statistical significance of both R&D expenditure and GDP per capita in producing more patent applications, this study indicates the single most significant effect of ‘R&D expenditure’.

This can be partly explained by the difference in the rate of R&D spending out of GDP across countries. From the above findings, it can be confirmed that allotting more budget for R&D is likely to be the most effective policy in terms of increasing the number of patent applications.

In addition, the comparison of the National Innovation System, especially between the US and South Korean innovation system showed that there are very little differences in the institutional National Innovation System itself, but rather the operational inefficiency and poor management of the National Innovation System leads to low level of knowledge diffusion, technology transfer and finally the number of PCT patent applications.

Till now, the patent system has served a critical role to promote innovation, to diffuse the technical knowledge and to direct the direction of technological changes. However, rapidly changing environments such as increasing globalization, overwhelming use of the Internet, the rapid development of Artificial Intelligence will require us to face new challenges that have not been observed in the past. For this reason, more well-informed patent policies are required to meet the new challenges and to ensure the patent system continues to fulfil its role for the major driver for national innovation.

In this respect, this study tries to contribute to the improvement of the National Innovation System by providing a meaningful tool to understand the mechanism of the patent system from a global perspective.

Appendix Table A. Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
PCT	721	3535	10171.42	3	61973
GDPpc	760	28122	20399.49	443.314	103000
RnD	559	38325	82443.9	592.91	484000
RnDGDP	559	1.858	.978	.306	4.553
rsrchrmn	544	3106	1897.347	110.095	8250.474
HDI	600	.828	.091	.493	.946
OECD	760	.75	.433	0	1
eduyr	351	10.933	2.102	5.302	14.314
pstab	720	.418	.799	-2.021	1.76
RDSubsidy	634	.117	.128	-.06	.45

Appendix Table B. List of Countries with basic statistics (2018)

ID	country	PCT	GDP per capita (US Mil.$)	GDP (US Mil.$)
1	Australia	1,674	57,305	1,432,195
2	Austria	441	51,513	455,737
3	Belgium	3	46,556	531,767
4	Brazil	570	8,921	1,868,626
5	Canada	1,912	46,125	1,709,327
6	Chile	202	15,923	298,231
7	China	55,204	9,771	13,608,152
8	Czech Republic	124	22,973	244,105
9	Denmark	457	60,596	351,300
10	Finland	1,007	49,960	275,683
11	France	3,538	41,464	2,777,535
12	Germany	1,430	48,196	3,996,759
13	Greece	59	20,324	218,032
14	Hungary	113	15,939	155,703
15	India	920	2,016	2,726,323
16	Ireland	16	77,450	375,903
17	Israel	1,436	41,614	369,690
18	Italy	434	34,318	2,073,902
19	Japan	48,630	39,287	4,970,916
20	Korea	16,990	31,363	1,619,424
21	Malaysia	138	11,239	354,348
22	Mexico	196	9,698	1,223,809
23	Netherlands	917	52,978	912,872
24	New Zealand	183	41,966	205,025
25	Norway	346	81,807	434,751
26	Poland	201	15,424	585,783
27	Portugal	68	23,146	237,979
28	Russia	1,046	11,289	1,657,554
29	Saudi Arabia	40	23,219	782,483

30	Singapore	654	64,582	364,157
31	Slovenia	63	26,234	54,235
32	South Africa	68	6,340	366,298
33	Spain	932	30,524	1,426,189
34	Sweden	1,405	54,112	551,032
35	Switzerland	78	82,839	705,501
36	Thailand	59	7,274	504,993
37	Turkey	1,014	9,311	766,509
38	Ukraine	143	3,095	130,832
39	United Kingdom	3,885	42,491	2,825,208
40	United States	55,279	62,641	20,494,100

Appendix Table C. R&D expenditure as percentage of GDP (2000-2017)

(unit : %)

	Korea	Japan	US	UK	China
2000	2.1802	2.9057	2.6288	1.6265	0.8932
2001	2.3411	2.9718	2.6483	1.6190	0.9403
2002	2.2738	3.0139	2.5593	1.6254	1.0579
2003	2.3515	3.0430	2.5645	1.5895	1.1204
2004	2.5325	3.0295	2.5024	1.5423	1.2150
2005	2.6262	3.1810	2.5170	1.5612	1.3079
2006	2.8307	3.2784	2.5576	1.5829	1.3685
2007	3.0003	3.3396	2.6316	1.6217	1.3730
2008	3.1234	3.3372	2.7679	1.6231	1.4447
2009	3.2932	3.2314	2.8127	1.6825	1.6621
2010	3.4659	3.1371	2.7354	1.6606	1.7099
2011	3.7436	3.2448	2.7653	1.6649	1.7754
2012	4.0255	3.2091	2.6817	1.5938	1.9058
2013	4.1485	3.3150	2.7097	1.6394	1.9902
2014	4.2887	3.4002	2.7192	1.6591	2.0211
2015	4.2170	3.2775	2.7174	1.6682	2.0564
2016	4.2274	3.1408	2.7597	1.6821	2.1083
2017	4.5532	3.2043	2.7880	1.6638	2.1286

Appendix Table D. Number of PCT applications (2000-2018)

	Korea	Japan	US	UK	China
2000	1,573	9,447	38,093	5,008	745
2001	2,314	11,687	43,213	5,657	1,656
2002	2,511	13,880	41,283	5,741	951
2003	2,942	17,096	41,314	5,532	1,166
2004	3,565	19,850	43,662	5,341	1,592
2005	4,690	24,290	47,243	5,171	2,437
2006	5,918	26,421	51,852	5,188	3,827
2007	7,060	26,935	54,597	5,548	5,400
2008	7,911	28,027	52,053	5,273	6,081
2009	8,025	29,291	46,055	4,627	8,000
2010	9,639	31,523	45,228	4,411	12,917
2011	10,413	37,972	49,366	4,226	17,471
2012	11,869	42,787	52,011	4,128	19,924
2013	12,439	43,075	57,683	3,894	22,927
2014	13,137	41,292	61,973	4,240	27,088
2015	14,592	43,097	57,589	4,100	31,045
2016	15,595	44,495	56,679	4,008	44,462
2017	15,790	47,425	56,303	3,933	50,655
2018	16,990	48,630	55,279	3,885	55,204

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