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Patent, R&D and Internationalization for Korean healthcare industry

Hyun-Jung Nam [a], Yohan An [b,*]

[a] BK 21 Center, Graduate School of International Studies, Dong-A University, Busan, Republic of Korea
[b] Department Finance & Accounting, College of Business Administration, Tongmyong University, Busan, Republic of Korea

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ABSTRACT

Using panel data, this study investigates how Patent and R&D expenditures affect internationalization in Korean healthcare industry. Korean healthcare industry is designated as one of the core bread and butter industries. Tremendous government investments in Korean healthcare industry are expected to increase Patent and R&D expenditures, causing internationalization for Korean healthcare industry. In material way, this study focuses on testing spillover effects between Patent and R&D expenditures on internationalization.

Empirical analysis is done by the panel GLS estimation using 47 Korean healthcare firms' 7 years' panel data. As empirical results, we find internationalization of Korea healthcare industry is positively affected by Patent and R&D expenditures but their impacts are limited. In addition, we find there is a non-linear relation between Patent and R&D expenditures on internationalization measured by exports so that spillover effects are significantly confirmed.

We propose several suggestions that government lead R&D policy does not effectively increase internationalization, and spillover effects of Patent and R&D expenditures differently affect internationalization following internationalization phase. Practically, government lead R&D investments should be disseminated to private sector to vitalize internationalization of Korean healthcare industry.

1. Introduction

In industrial economics, Patent and research and development (hereinafter R&D) expenditures lead firms to internationalization because they improve firm's innovation activities (Bleaney and Wakelin, 2002; Penner-Hahn and Shaver, 2005). As a result of high level of innovation caused by Patent and R&D expenditures, firms compete in export market and become internationalization (Aw et al., 2007, 2011).

In reality, however, the relationship between internationalization and Patent and R&D expenditures has remained little empirical findings or a puzzle. Ample previous studies do not clarify the distinction between government and firm level R&D expenditures effects on internationalization. García-Quevedo (2004) argues that public R&D differs from private R&D and Griliches (1981) criticize that examination of R&D effects mainly focus on firm level and US firms. Outstanding feature of Patent and R&D expenditures in emerging countries are that government designate strategic industry considered as a high value-added business such as healthcare industry. In emerging countries, tremendous capital investment and cutting-edge technology of high value-added business depends heavily on government sector's Patent and R&D expenditures requires.

Furthermore, many previous studies focus on the impact of R&D expenditures on Patent application (Cincera, 1997) or spillover effects of Patent (Bottazzi and Peri, 2003) and exports (Girma et al., 2008). However, we know little about that the spillover effects of Patent and R&D expenditures are differently applied in internationalization since Patent duration and the speed of R&D spillover. Our contribution stems from the investigation of these arguments and the purpose of study is to investigate the impact of Patent and R&D expenditures on internationalization of Korean healthcare industry using panel data.

The Korean healthcare industry provides an excellent circumstance to test the purpose of this study. The healthcare industry in Korean is rapidly increasing the importance. The size of healthcare industry in Korea is estimated as 18.6 billion dollars which accounts for 1.8 per cent of R&D expenditures in the world as of 2009. Specifically, healthcare expenditures amounts of Korea ranked the highest within OECD countries. This is because the Korean healthcare industry has been considerably implemented by information technology (IT) development as well as tremendous Korean government's investments of Patent and R&D expenditures for healthcare industry. Furthermore, the Korean government designates healthcare industry as future bread and butter and expects to be core exports industry. This part is very critical for the development of national healthcare industry and sustainable internationalization.

The effectiveness of government-driven investments of Patent and R&D expenditures in an emerging country such as Korea highly propose

* Corresponding author.
E-mail addresses: hjnam@donga.ac.kr (H.-J. Nam), accahn@tu.ac.kr (Y. An).

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two interesting questions that we address in this study. The first question we propose in this study is that does the government sector's contribution of Patent and R&D expenditures expect to increase internationalization by stimulating innovation of Korean healthcare industry?

Generally, Patent and R&D expenditures of most emerging countries such as Korea, China and Taiwan are led by government rather than privates. However, the effects of government-driven Patent and R&D expenditures on exports are controversial. Government-driven Patent and R&D expenditures encourage R&D activities for private sectors by complementing insufficiency (An and Ahn, 2016), thus positively affect exports as a proxy of internationalization. On the contrary to this positive view, government-driven Patent and R&D expenditures negatively affect exports because they act as "crowding-out effect", causing underinvestment in Patent and R&D for private sector and misallocation of resources (Wallsten, 2000). Based on controversial views of government-driven Patent and R&D expenditures on exports, this study examines whether Korea's large Patent and R&D expenditures driven by government positively affect exports as a measure of internationalization or not.

The second question we propose in this study is that how spillover effects of Patent and R&D expenditures affect internationalization of Korean healthcare industry? In general, the establishment of intellectual property such as Patent promotes knowledge innovation and encourages faster economic growth and exports. Patent is special means for spillover of R&D and innovation as well as R&D expenditures increase Patent. There are two conflicting views of Patent on R&D. The longer the Patent duration is, the faster R&D spillover is because Patent registration means innovation itself whereas the shorter the Patent duration is, the higher the speed with R&D spillover is since public can use technology without payment after expiration of Patent. Even though R&D expenditures and Patent are closely related, their impacts differently affect internationalization as a measure of exports. Hsu et al. (2015) find a curvilinear U-shaped relationship between R&D and innovation in Taiwan high-tech firms, suggesting that the fruit of R&D is shown after critical levels of intensity and diversity.

Thus, we expect there is a non-leaner relationship between the spillover of Patent and R&D expenditures, and internationalization. Further, it is worth to distinguish the spillover effects of them for internationalization. Based on that, we explore that the non-linear relationship between Patent and R&D expenditures on internationalization to test spillover effects.

We find that government-driven Patent and R&D expenditures do not increase internationalization of Korean healthcare industry. This result implies that success of internationalization should be driven by private sector or firm level as well as government sector. We find that spillover effects (nonlinear relationship) exist in both Patent and R&D expenditures with internationalization. However their spillover effects have different influence on internationalization stage due to two-way relationship between Patent and R&D expenditures.

The findings of this study provide important implications with researchers and policy makers. First, the importance of R&D expenditures has been recognized as a consequence of growing firm value and innovation. However, despite the importance of Patent and R&D expenditures, existing studies largely ignored the impact of Patent and R&D expenditures on internationalization. The case of Korean healthcare industry provides an excellent opportunity to examine the role of Patent and R&D expenditures on internationalization due to rapidly increased national exports. Second, Korea, as a late industrialized country, is one of the few nations that has successfully transformed from imitator to innovator (Amsden, 1992; Kim, 1998). Korea is one of the highest R&D investments countries in the world. Specifically, Korea was ranked the second highest expenditures-to-GDP ratio country which was 4.36 per cent in the world following Israel R&D as of 2012 (Ministry of Science, 2013). Thus, this study provides good opportunity how increased Patent and R&D expenditures driven by government efficiently affect internationalization of Korean healthcare industry.

This paper starts with this introduction section, which provides the purpose of this study and contribution. Section 2 reviews the literature and addresses the research question. Then Section 3 discusses the methodology. In Section 4, the empirical results begin with panel data analysis. Finally, Section 5 presents conclusions relevant to fulfill the purpose of the paper.

2. Literature review and research question

In this era, many firms are getting their resource invest in R&D activities more and more because the technical revolution and the patent management are core elements to strengthen their competitiveness and sustainable growth. Investment in R&D represents an activity that can increase the value of a firm's intangible assets. The market value of a firm represents the market valuation of expected future profit streams generated from investment in R&D. These, in turn, are based on an assessment of the market return to the firm's tangible and intangible assets. While not all investments in R&D generate profits (Jensen, 1986), on average, any investment in a firm's intangible assets should be expected to increase the firm value (Bosworth and Rogers, 2001).

The primary research question addressed by the previous research is that the larger the potential growth opportunities, the higher the potential profits from developing the product and hence the greater the incentive to invest in R&D. Moreover, the development of R&D is increasingly in many industries, and R&D activities enhance firm value since innovation resulted from Patent and R&D increase firm's excessive returns and stock price (Griliches, 1981; Hirschey and Weygandt, 1985; Bublitz and Ettredge, 1989; Chaney and Devinney, 1992). Ballester et al. (2003) imply that R&D expenditures are critical factor for management to reinforce firm value because R&D expenditures stimulate innovation. Many domestic researches support R&D expenditures create firm's future economic benefits (Paek et al., 2004; Choi et al., 2007).

In line with the arguments of innovation, the growth and firm value will be improved, if they take the patent by investing in R&D. Lev (2001) argues that high technology is a value driver in innovative and leading industry such as healthcare industry so that Patent through R&D activities is the most important factor for firms to increase their earnings. Amin and Thrift (1984) and Lall (1985) argue that capabilities of R&D facilitate increasing of export and Dhanaraj and Beamish (2003) support positive impact of R&D expenditures on return at international market. More recently, Ruff (2015) argues that the investment of Patent and R&D enable firms to achieve sustainable management after tracing current state of practice of a corporate foresight unit of a multinational automotive company. Cin et al. (2016) find positive effects of the public R&D expenditure on the productivity for Korean small and medium sized firms. Hence, increased productivity of firms leads firm to competent exporter.

The general consensus is that innovation stimulates exporting and also exporting is supported by innovation (Girma et al., 2008). Therefore, we turn to the previous researches to test the positive effects of innovation measured as Patent and R&D on internationalization. With this building around these prior works, we propose research question that how government driven Patent and R&D expenditures would result in internationalization of Korean healthcare industry.

The spillover of Patent and R&D expenditure is critical factor to increase firm value or internationalization. According to Sougiannis (1994), R&D expenditures increase firm's earnings and stock price but their effects are indirect and take long time because of lagged R&D spillover. Cincera (1997) and Bottazzi and Peri (2003) investigate spillover with Patent and R&D expenditures using panel data. They find technological spillovers are due to new knowledge and innovation based on Patent and R&D. Pakes (1985), Griliches (1980) and Oguamanam (2010) suggest that Patent as output of R&D expenditures positively

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affects exports when Patent spillover removes uncertainty of R&D expenditures in initial stage.

Bhaduri and Ray (2004) find that spillover of technical competency is a critical determinant factor of exports for India's Pharmaceutical firms. Penner-Hahn and Shaver (2005) also provide evidence that the positive association between R&D expenditure and exports for Japanese Pharmaceutical firms. Ivus (2015) and Briggs and Park (2014) also find that Patent rights have a strong impact on the export and licensing activities of firms in developed countries.

In well established literature, positive spillover effects externalized by Patent and R&D expenditures are critical to internationalization. Turning to first research question in our study, we expect that spillover effects of Patent and R&D expenditures will increase internationalization of Korean healthcare industry. However, we expect that their spillover effects will differently affect internationalization phase because of two-way relationship between Patent and R&D expenditures. It is necessary groundwork for the second research question that how spillover effects of Patent and R&D expenditures affects internationalization of Korean healthcare industry.

3. Methodology

This study uses panel data set of Korean healthcare firms listed on the Korean Stock Exchange (KSE). As of 2014, all listed manufacturing firms on the KSE are 445 out of all 921 firms. According to International Standard Industrial Classification (ISIC), C21000 as Manufacture of pharmaceuticals, medicinal chemical and botanical products out of Section C Manufacturing (10–33) is selected. All data in this study is obtained from DataGuide database provided by FnGuide and the Korean Intellectual Property Office (KIPO) under the permission of Dong-A University, respectively. The final sample consists of panel data of total 306 firm-year data from 47 pharmaceuticals, medicinal chemical and botanical products firms listed on the Korea Stock Exchange (KSE) over seven-year period from 2008 to 2014 (See Table 1). During the sample period, five firms are newly listed out of 47 firms, and some missing values are found. Thus, unbalanced panel data is employed in this study.

3.1. Dependent variable

In this study, export *(Export)* is used as a proxy of internationalization following Kim and Lyn (1986) and Qian (2002) because export is the most basic strategy to explain internationalization.

Table 1
Industry distribution of listed firms on the KSE.

Industry	Number of firms
Agriculture, forestry and fishing (A01–A03)	5
Mining and quarrying (B05–B08)	1
Manufacturing (C10–C33)	445
Manufacture of pharmaceuticals, medicinal chemical and botanical products (C21000)	**47**
Electricity, gas, steam and air conditioning supply & Water supply (D35, E36–E39)	11
Construction (F41–43)	31
Wholesale and retail trade (G45–47)	61
Transportation and storage (H49–H53)	22
Accommodation and food service activities (I55–I56)	1
Information and communication (J58–J63)	27
Financial and insurance activities (K64–66)	208
Real estate activities (L68)	28
Professional, scientific and technical activities (M69–M75)	70
Administrative and support service activities (N77–N82)	5
Public administration and defense & Education (O84–P85)	1
Human health and social work activities & Arts, entertainment and recreation (Q86–Q88, R90–R93)	4
Other service activities (S94)	1
Total	921

3.2. Independent variables

This study uses two independent variables, R&D and Patent as proxies of innovation. R&D *(R&D)* is measured as total R&D expenditures divided by total sales following Schoenecker and Swanson (2002). Patent *(Patent)* is calculated as the number of patent (Jee and Sohn, 2015; Dutta and Weiss, 1997).

3.3. Control variables

Four control variables that may affect internationalization are cash holding, firm age, firm size, and firm growth ratio. Cash holding (*Cash*) is the most important slack resource to support internationalization (Kuan et al., 2012). Cash holding is calculated as cash and cash equivalent divided by total asset subtract cash and cash equivalent. Firm age *(Age)* is employed to control heteroscedasticity and measured as the natural logarithm of firm age. To control for size effects, the natural logarithm of the total sales is included as a proxy for size (Size). Growth (*Growth*) is firm's sale growth ratio, measured by annual percentage change of sales.

4. Basic specification

This study uses the following two equations to test the impact of Patent and R&D expenditures on internationalization.

$$Export = \alpha + \beta_1 Patent + \beta_2 Patent^2 + \gamma_i Cash + \gamma_2 Age + \gamma_3 Size + \gamma_4 Growth + \varepsilon \quad (1)$$

$$Export = \alpha + \beta_1 R\&D + \beta_2 R\&D^2 + \gamma_i Cash + \gamma_2 Age + \gamma_3 Size + \gamma_4 Growth + \varepsilon \quad (2)$$

There is possible non-linear relationship between Patent and R&D expenditures on exports. In Eqs. (1) and (2), we employ two squared variables, $Patent^2$ and $R\&D^2$ to test non-linear relationship.

In this empirical model, we do not consider interaction effect between Patent and R&D expenditures (*Patent*R&D*). Interaction variable (*Patent*R&D*) is available when the causal relationship between independent variable and moderate variable is not significant (Baron and Kenny, 1986). When interaction effect between Patent and R&D expenditures (*Patent*R&D*) is considered, one variable is classified as independent variable then another variable is classified as moderate variable. In this study, the causal relationship runs in both Patent and R&D expenditures. If we consider interaction effect between Patent and R&D expenditures (*Patent*R&D*) in empirical model, there can be serious multicollinearity issues in Patent and R&D expenditures being too highly correlated with Patent and R&D expenditures. Therefore, we do not consider interaction effect between Patent and R&D expenditures (*Patent*R&D*) to avoid multicollinearity issues.

As this study utilizes panel data, panel study methodology should be considered. The advantage of panel data methodology lies in more robust information, more variability, less colliearity among variables, more degrees of freedom and more efficiency (Baltagi, 2005). An F-test and Breusch-Pagan LM (Lagrangian Multiplier) test are applied to test the appropriateness of the fixed effects estimation and random effects estimation correspondingly. Then, we test the Hausman test (1978) for choosing the most appropriated model. Finally, we add two tests; 1) Wooldridge test and 2) Wald Test to find auto-correlation in error term and heteroscedasticity of fixed effects estimation and random effects estimation. In this study, we adopt the panel GLS estimation with auto-correlation and heteroscedasticity as a main panel data analysis method.

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Table 2
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Export (%)	306	10.857	16.653	0	76.684
Patent	329	8.924	20.910	0	158
Patent^2	329	515.556	2716.653	0	24964
R&D	323	0.032	0.060	0	0.511
R&D^2	323	0.004	0.022	0	0.261
Cash	323	0.076	0.091	0.000126	0.636
Age	336	21.854	12.996	0	52
Size	323	25.453	1.113	20.414	27.639
Growth(%)	312	13.339	63.414	−99.83	200.01

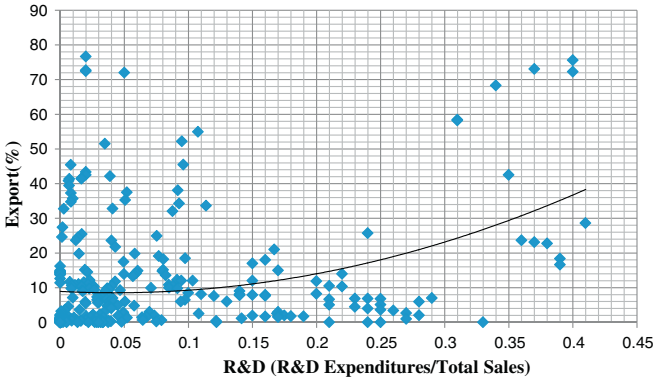

Fig. 1. The relationship between exports and R&D.

5. Findings

5.1. Descriptive statistics

Table 2 shows the descriptive statistics for variables. In previous Korean researches on internationalization, the average export portion of manufacturing industry account for 49.71 per cent (Kim and Lim, 2011) while that of healthcare industry remains only 10.85 per cent. This result suggests that competitiveness of Korean healthcare industry is relatively lower than manufacturing industry in spite of having high technical skills. According to the Korean Intellectual Property Office's investigation, Korea is ranked 5th highest Patent applications in the world following U.S., Japan, Germany, and China as of 2012. In this study, average Patent of healthcare industry is 8.924 which accounts for 10.8 per cent of all Korean Patents. The average of R&D expenditures shows 0.032 which is higher than that of manufacturing industry (0.013).

5.2. Correlation

Table 3 reports correlation among variables. R&D expenditures (*R&D*) and internationalization (*EXPORT*) are positively related, whereas Patent is negatively linked with internationalization (*EXPORT*) but statistically insignificant. Overall, there are few that are sufficiently large to cause any serious problems of multicollinearity.

5.3. Test of non-linearity

Patent and R&D expenditures are critical determinant factor of exports (Bhaduri and Ray, 2004; Penner-Hahn and Shaver, 2005). Oguamanam (2010) finds positive relationship between the innovation of pharmaceutical industry and exports but its innovation requires much sunk costs. Even though R&D expenditures increase firm value, R&D expenditures cause high wages (Himmelberg and Peterson, 1994; Hall, 2002). Guellec and Loannidis (1997) argue that sunk costs lead to the uncertainty of R&D expenditures so that the effect of R&D expenditures takes a long time. However, Oguamanam (2010) suggests that continuous innovation should be required because innovation increases exports. Based on these argues, the effect of R&D expenditures on exports is negative in initial stage but turn into positive as time passes. Thus, the impact of R&D expenditures on exports might be presented to non-linearity.

Penneder and Woerter (2014) argue innovation is positive 'escape effect' of competition, while the negative 'dissipation effect' exits at high level competition between firms. It means that the positive effect of Patent on exports can be reduced because high level of Patent causes high level of competition. Thus, non-linearity of Patent can be expected.

Fig. 1 shows the relationship between R&D expenditures and exports of Korean healthcare firms. In Fig. 1, R&D expenditures present quadratic function (U-shaped) and the effect R&D expenditures on exports changed at 0.06 level. Fig. 2 shows the association between Patent and exports of Korean healthcare firms and also appears to quadratic function (reverse U-shaped). The infection point of Patent and exports is 110.

5.4. Test of suitability of models

Before estimating the coefficients of variables, we test suitability of models to find our relevant panel data methodology as shown in Table 4. As a first step to analyze panel data, we implement *F*-test to find that panel methodology is more suitable for this study than Pooled-OLS. In addition, Breusch-Pagan LM test is conducted to find suitable models between pooled-OLS and random effects model considering panel characteristics. Then, we also conduct the Hausman test to adopt suitable panel data estimation. After having conducted the tests,

Table 3
Correlation analysis.

	Export	Patent	Patent^2	R&D	R&D^2	Cash	Age	Growth	Size
Export	1								
Patent	−0.001	1							
	(0.974)								
Patent^2	0.017	0.937***	1						
	(0.761)	(0.000)							
R&D	0.142**	0.008	−0.024	1					
	(0.012)	(0.882)	(0.659)						
R&D^2	0.049	0.029	−0.009	0.885***	1				
	(0.390)	(0.604)	(0.863)	(0.000)					
Cash	−0.066	0.032	0.036	0.054	0.014	1			
	(0.245)	(0.567)	(0.511)	(0.334)	(0.791)				
Age	−0.231***	−0.039	−0.014	−0.006	−0.004	−0.018	1		
	(0.000)	(0.483)	(0.802)	(0.911)	(0.937)	(0.736)			
Growth	0.051*	0.042	0.049	−0.032	−0.009	0.039	−0.116**	1	
	(0.081)	(0.453)	(0.381)	(0.572)	(0.870)	(0.488)	(0.040)		
Size	−0.016	−0.127**	−0.203***	0.049	0.019	−0.084	0.014	−0.011	1
	(0.770)	(0.022)	(0.000)	(0.381)	(0.726)	(0.130)	(0.796)	(0.844)	

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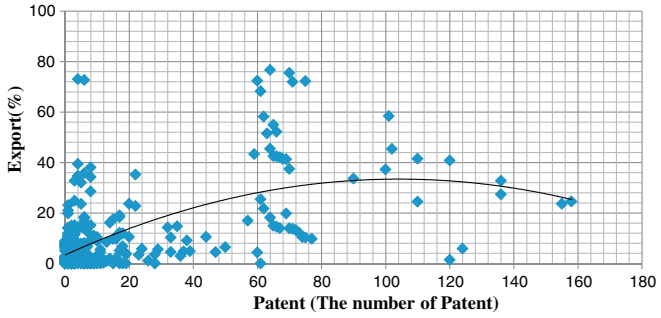

Fig. 2. The relationship between exports and patent.

we find that the random effects estimation is suitable for models (1) and (3), while fixed effects estimation is appropriate for model (2) and model (4).

However, Green (2000) suggests that the Hausman test becomes problematic when unbalanced panels are used, as the case in this study. Even though random effects estimation is more efficient than pooled-OLS and fixed effects estimation as a result of Breusch-Pagan LM test and the Hausman test, we should check auto-correlation in error term and heteroscedasticity in the panel data analysis.

As the result of Wooldridge test, auto-correlation in error term does not exist in models (1), (3), (5) and (7) whereas there is auto-correlation in error term in models (2), (4), (6) and (8). The result of Wald test shows heteroscedasticity in all models. Thus, we state that in overall, the panel GLS estimation with heteroscedasticity and random effects estimation as in models (1), (3), (5) and (7) based on Wooldridge test. In models (2), (4), (6) and (8), the panel GLS estimation with auto-correlation and heteroscedasticity is employed.

5.5. Panel regression results

The results of the relationship between Patent and exports present in Table 5. After conducting model diagnostic tests shown in Table 4, we select the panel GLS estimation with heteroscedasticity and random effects estimation as in models (1), (3), (5) and (7) as well as the panel GLS estimation with auto-correlation and heteroscedasticity is employed in models (2), (4), (6) and (8).

In model (1) without control variables, Patent is significantly positive with exports whereas model (2) including control variables does not find linear relationship between internationalization and Patent. This result can be interpreted as that the positive effect of Patent on internationalization is limited because internationalization depends on many factors. However, models (3) and (4) provide significant non-linear relationship between internationalization and Patent. Specifically, the relationship between internationalization and Patent shows significant reverse U-shape. This result suggests that increasing Patent positively affects internationalization but rather excessive Patent negatively affects internationalization.

This reverse U-shape result between internationalization and Patent could be interpreted as the short period effect of Patent on spillover. The shorter the Patent length is, the higher the speed with knowledge diffusion is, because after expiration anyone can use technology without payment. However, the long duration the Patent deters dissemination of knowledge diffusion, thus wasting capital and resources.

In Table 6, Models (5) and (6) show the linear relationship between internationalization and R&D. In model (5) not employing control variables, the linear relationship between internationalization and R&D is statistically significant whereas model (6) considering control variables provides do not provide statistical significance of the linear relationship between internationalization and R&D. Overall, these findings similar suggest that the linear relationship between internationalization and R&D is not significant because of many factors to affect internationalization.

Models (7) and (8) provide the non-linear relationship between internationalization and R&D expenditures. Both models provide statistical significance between internationalization and R&D. These curvilinear results means that much R&D expenditures negatively affect internationalization while excessive R&D cause positive effects for internationalization.

These curvilinear results could be interpreted as R&D spillover (Cincera, 1997; Bottazzi and Peri, 2003). Cincera (1997) and Bottazzi and Peri (2003) test technology spillover using the number of Patent and lagged R&D expenditures. They find evidence that the positive relationship between R&D expenditures and Patent since R&D expenditures stimulate new idea, thus increasing the number of Patent. Accordingly, the results of this study expand R&D spillover from previous researches.

Table 4
Summary of model diagnostic test.

Dependent variable: exports
Independent variable: patent

	Model (1)			Model (2)			Model (3)			Model (4)		
	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS
F test	48.66***			48.37***			50.45***			49.47****		
Breusch & Pagan LM	686.19***			661.32***			687.36***			662.03***		
Wooldridge test	2.020			5.048**			1.981			5.517**		
Hausman test	1.45			9.32*			1.66			9.24*		
Wald test (p value)	0.000***			0.000***			0.000***			0.000***		

Dependent Variable: Exports
Independent Variable: R&D Expenditures

	Model (5)			Model (6)			Model (7)			Model (8)		
	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS
F test	47.73***			49.26***			50.68***			49.96***		
Breusch & Pagan LM	696.01***			669.99			697.53***			671.05***		
Wooldridge test	0.1279			0.0008***			0.1279			0.0010***		
Hausman	0.35			7.03**			0.00			7.40		
Wald test (p value)	0.000***			0.000***			0.000***			0.000***		

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Table 5
Patent and export: Pooled OLS, fixed and random effects model for health care industry.

	Model (1)			Model (2)			Model (3)			Model (4)		
	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS
cons	10.808***	10.972***	8.463***	−29.535	−15.593	24.061	10.730***	11.063***	9.051***	−28.888	−15.819	−22.942
	(19.87)	(4.64)	(25.57)	(−1.56)	(−0.85)	(−0.85)	(28.64)	(4.74)	(31.85)	(−1.53)	(−0.87)	(−0.96)
Patent	−0.043	−0.012	0.070***	−0.011	0.008	0.024						
	(−0.74)	(−0.24)	(2.79)	(−0.61)	(0.14)	(0.42)						
$Patent^2$							−0.008	−0.005*	−0.005**	−0.018*	−0.007**	−0.008**
							(−1.35)	(−1.81)	(−2.44)	(−1.86)	(−2.13)	(−2.17)
Cash				−8.633	−9.728	−6.521				−8.679	−9.688	−7.250
				(−1.57)	(−1.26)	(−0.21)				(−1.58)	(−1.25)	(−.024)
Age				0.246	0.054	−0.251				0.245	0.053	−0.258**
				(1.45)	(0.46)	(−1.94)				(1.44)	(0.42)	(−1.98)
Size				1.499**	0.978	1.447				1.472**	0.996	1.556*
				(2.03)	(1.40)	(1.54)				(2.00)	(1.44)	(1.67)
Growth				0.032***	0.033***	0.017				0.033***	0.032***	0.016
				(3.22)	(3.45)	(1.48)				(3.23)	(3.39)	(1.40)
Chi^2 (p value)	0.460	0.813	0.005***	0.000***	0.013**	0.020**	0.176	0.416	0.014**	0.000***	0.013**	0.022**
Adj. R^2	0.041	0.021		0.099	0.071		0.033	0.01		0.098	0.071	
Number of obs	293	299	299	284	298	287	293	299	299	284	289	287

To summarize, in the initial stage of internationalization, R&D expenditures can plays a role to lay groundwork for internationalization. As progress internationalization, R&D expenditures positively affect internationalization (U-shaped between R&D expenditures and internationalization). In the middle stage of internationalization, R&D expenditures increase the number of Patent (Cincera, 1997; Bottazzi and Peri, 2003). However, after the middle stage of internationalization, excessive Patent negatively turns into internationalization due to waste of resources and human capital (reverse U-shape between Patent and internationalization).

The empirical results of this study provide evidence that internationalization of healthcare industry as a high-tech industry is heavily affected by Patent and R&D expenditures so that spillover effects are significantly confirmed. However, spillover of Patent and R&D expenditures differently affects internationalization phase of Korean healthcare industry.

6. Conclusion

The healthcare industry is considered as an industry of great Patent information and R&D expenditures for the development of internationalization. Coinciding with this, sustainable Patent information and R&D expenditures should be undertaken to improve internationalization of Korean healthcare industry. We find the evidence that Patent and R&D expenditure positively affect internationalization of Korean healthcare industry, but their positive impacts on internationalization is limited. Thus, government-driven Patent and R&D policy does not effectively increase internationalization of Korean healthcare industry.

We confirm the non-linear relationship between internationalization and Patent as well as R&D expenditures of Korean healthcare industry, thus spillover effects exist in both Patent and R&D expenditures. However, spillover effects of Patent and R&D expenditures have different influence on internationalization stage of Korean healthcare industry.

Table 6
R&D and export: pooled OLS, fixed and random effects model for health care industry.

	(5)			(6)			(7)			(8)		
	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS	Fixed effects model	Random effects model	GLS
R&D	21.196**	22.421**	32.726***	11.990	17.198*	32.333						
	(2.18)	(2.36)	(3.74)	(1.16)	(1.74)	(1.23)						
$R\&D^2$							22.421**	36.371***	38.124***	17.642**	19.355*	18.012*
							(2.36)	(2.64)	(2.65)	(1.96)	(1.83)	(1.91)
Cash				−8.486	−9.145	8.831				−9.907*	−9.709	−1.121
				(−1.53)	(−1.15)	(0.775)				(−1.73)	(−1.19)	(−0.37)
Age				0.240	−0.008	−0.260**				0.251	0.014	−0.250*
				(1.42)	(−0.07)	(−2.06)				(1.50)	(0.12)	(−1.83)
Size				1.436*	0.596	1.283				1.560**	0.764	1.604*
				(1.88)	(0.83)	(1.37)				(2.09)	(1.08)	(1.72)
Growth				0.033***	0.027***	0.014				0.033***	0.027***	0.012
				(3.29)	(2.83)	(1.24)				(3.34)	(2.83)	(1.10)
cons	10.146***	10.421***	8.133***	−28.104	−4.393	−22.757	10.421***	10.679***	5.648***	−30.709	−8.684	−24.018
	(21.81)	(4.54)	(21.19)	(−1.45)	(−0.23)	(−0.95)	(4.54)	(4.79)	(13.05)	(−1.62)	(−0.47)	(−1.00)
Chi^2 (p value)	0.029	0.018	0.000	0.003	0.004	0.040	0.109	0.101	0.002	0.005	0.008	0.044
Adj. R^2	0.030	0.025		0.098	0.059		0.032	0.099		0.980	0.054	
Number of obs	293	306	306	284	296	294	293	306	306	289	296	306

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This study contributes to the academic literature in several ways. First, unlike previous studies, this study supports the importance of technology capability (Patent and R&D expenditures) of Korean healthcare industry on internationalization. However, this study restrictively determines that technology capability can be applied in internationalization of the healthcare industry. Second, results obtained with panel data analysis show that both Patent and R&D expenditures exhibits nonlinear relationship with internationalization. However, the shape of nonlinear of Patent with internationalization is inverted U-shaped whereas R&D expenditures on internationalization. This result proposes that spillover effects exist but differently affect internationalization following internationalization phase.

Based on the academic literature contribution, we propose some practical contributions to the government R&D policy. The empirical evidence of this study suggests that government-driven R&D investments fail to draw innovation of Korean healthcare industry. For China as an example of emerging country, R&D investments from regional firms, universities and research institutes strongly affects innovation system and contingencies in economy (Jiao et al., 2016). Therefore, in order to vitalize internationalization of Korean healthcare industry, government-driven R&D investments should be disseminated to private sector.

We find that Patent negatively turns into internationalization in the long duration. It suggests that short Patent duration leads to large spillover, thereby increasing internationalization of Korean healthcare industry. Thus, proper Patent duration policy such as renewal and grace period of Patent can lead internalization of Korean healthcare industry by optimal R&D investments from Korean government.

There are several potential limitations in this study. Similar to prior research on internationalization, this study is subject to problems that occur when exports uses as a proxy of internationalization. Although this study attempts to control the factors affecting internationalization, there could be omitted variables that affect the association between Patent and R&D expenditures with internationalization.

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Hyun-Jung Nam earned her Ph.D. in Business Administration (Major: Finance,) at Pusan National University, Busan, Republic of Korea. She is a Research Professor at BK21 center, Dong-A University, Republic of Korea

Yohan An earned his Ph.D. in Business Administration (Major: Finance, Minor: Accounting) at RMIT University, Melbourne, Australia. He is Assistant Professor (tenured track) and Head of Department at Department of Finance & Accounting, Tongmyong University, Republic of Korea.

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