Impacts of innovation type SME's R&D capability on patent and new product development

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Abstract

Purpose – This study aims to verify the effectiveness and efficiency of corporate technology innovation activities.

Design/methodology/approach – This study empirically analyzes the effects of research and development (R&D) capability on patent and new product development achievements on innovation-type small- and medium-sized enterprises (SMEs) by using the "Report on Korean Innovation Survey 2010: Manufacturing Sector" data released by the Science and Technology Policy Institute.

Findings – The results of the study indicate that staffing of the concentration of R&D human resource team and efforts toward open innovation are essential factors for the creation of corporate performance. The number of persons of the concentration R&D team in particular makes up essential resources for patent acquisition and new product development. In addition, in case of an SME's with relatively poor resources, it is necessary to acquire resources, both material and immaterial, learn from the external R&D activities and internalize those into key corporate capabilities rather than step up the R&D activities on their own.

Originality/value – The results of this study indicate that innovative small enterprises need to secure the number of R&D human resource members for maintaining sustainable competitiveness and securing market share. Therefore, a strategy is needed that would enable employing and raising excellent human resource in the quantitative and qualitative aspects. However, in the circumstances that small enterprises suffer difficulty in securing professional human resource for R&D compared to large enterprises, as there is a limitation for securing human resource for R&D from only the dimension of enterprises, governmental and political support is thought to be necessary for securing good-quality human resource for R&D. Accordingly, the results of this study provide many implications for the necessity of detailed methodology on how to expand professional human resource for R&D among supporting policies for technical innovative enterprises and to establish innovative strategies of enterprises.

Keywords New product development, Technology innovation, Innovation-type SMEs, Patent performance

Paper type Research paper

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1. Introduction

As a form of innovation with science and technology as a driving force, technology innovation is an innovative activity that creates new values through creative combination of production resources, such as process, market, resources and organization (Schumpeter, 1934). Technology innovation causes business fluctuations by giving economy a jolt by means of developing new markets, changing the manner of commodity supply and generating dynamic gains as well as advancement of technology. Moreover, technology innovation occurs irregularly depending on the age concerned, and, once in place, it forms a cluster, thus playing the leading role in economic development (Schumpeter, 1934).

Interest in the factors determining corporate technology innovation as well as in the studies showing that technology innovation affects the market structure and corporate management performance has steadily been running high. Preceding studies have come up with various models of technology innovation processes and continuous discussions on causes and result variables. and all of these is emphasizing the importance of continuous R&D. As corporations can find factors enhancing added values of products, based on R&D, and create cost reduction effects, technology innovation makes up a major source of acquiring competitive edges (Tidd and Bessant, 2009).

Besides, there are studies on the attributes of new technology-based small firm (NTBF) similar in concept to innovation type of small- and medium-sized enterprises (SMEs) in advanced economies. Studies on NTBF's attributes as resources and capabilities (Aspelund *et al.*, 2005; Barney, 2001; Granstrand, 1998; March-Chorda and Yague-Perales, 2000; Löfsten, 2016; Sarason and Tegarden, 2001) and studies that have compared differences between the innovation type of SMEs and non-innovative ones (Baldwin and Johnson, 1996; Cohen and Levinthal, 1990; Kwak and Suh, 2010; Lee *et al.*, 2008) make up the bulk of such studies.

Unlike general expectations that innovation-type SMEs would excel the average ones in terms of the input of technology innovation and performance, assertions are recently made that differing performance could result depending on the industrial life cycle, stages of corporate growth, core business resource (such as business planning and localization and innovation resources) and core competencies (Balconi *et al.*, 2004; Burgelman *et al.*, 2009; Coombs and Beirly, 2006; Keizer *et al.*, 2002; Hall and Bagchi-Sen, 2002; Parida and Örtqvist, 2015; Park, 2012).

Besides, discussions on the enhancement of effectiveness and efficiency of technology innovation are surfacing, as cases are detected where no actual corporate performance is made in spite of increased R&D capabilities. Accordingly, this study, which is based on previous studies on the attributes and performance of innovation-type SMEs, proposes to analyze variables that lead to the achievements of technology innovation and to ascertain the implications for innovation-type SMEs to grow steadily into mid- and large-sized corporations.

To this end, the study empirically analyzes the relationships of R&D capability and performance, and the variables essential for technology innovation by using the raw data of the "Report on Korean Innovation Survey 2010: Manufacturing Sector" released by the Science and Technology Policy Institute (STEPI). Measurement was made after performance variables were divided into patents, which are a form of direct performance, and new product development, which is a form of indirect performance. Patents are perceived as data universally used for conducting a quantitative study related to the traits of R&D and performance, and actually a typical data that can represent innovation activities in all the areas, featuring long-term accumulation (Griliches *et al.*, 1991; Pérez-Cano and Villén-Altamirano, 2013). Therefore, it is highly

justifiable to use patent information in analyzing the relationships between technology innovation and corporate performance.

At the same time, new product development is a corporate strategic management activity, and as such no less than a work of art where all the corporate capabilities converge. If a corporation is to grow without letup, the corporation should cope dynamically with rapidly changing market environments and provide new products or services in accordance with changes in both existing and new customers. Therefore, identifying and analyzing the impact of new product development on company performance is essential to establishing a corporate strategy for resource concentration.

Prior to empirical analyses, the study is conducted as follows:

First, the study has carried out an examination of traits of technology innovation and innovation-type SMEs, the theoretical background of relationships between corporate R&D capability and performance and examinations of preceding studies. Second, the study has come up with research tasks, and set up a research model for empirical analyses. Third, the study has come up with data for verifying the hypotheses of the study, manipulative definition of measured variables and the analytical methods. Thereafter, the study has conducted empirical analyses of its hypotheses, and has come up with the results of analyses and their implications.

2. Theoretical background and literature review

2.1 Technology innovation

Technology innovation means activities advancing a corporation's dynamic gain through combination of new production resources, such as new products or services, new processes, new resources, new market exploration and new management organization (Schumpeter, 1934). As factors are found that enhance additive values of products by means of technology innovation, production of commodities of new qualities and reduction of costs take place; technical innovation makes up major sources for a corporation to acquire competitive edges (Tidd and Bessant, 2009). That is, technology innovation is defined as innovation by means of changes and advancement in science and technology, and new markets come into being or go out of existence accordingly as new technology and products come into being and goes so far as to induce the country to change. Therefore, technology innovation has potentials to change a corporation on a small scale to the world as a whole on a larger scale.

Technology innovation is divided into radical innovation and incremental innovation, continuous innovation and discontinuous innovation, product innovation and process innovation and so forth, depending on the speed or width of innovation.

Radical innovation means introducing products or services having new functions, and incremental innovation means changes in the existing technological system such as improvement of quality or cost reduction rather than changes in new functions. Continuous innovation means improvement or strengthening of the existing industrial structure, and discontinuous innovation means creating next-generation products and industrial restructuring. Product innovation means development of new products or improvement of the performance or functions of the existing products. Process innovation means adoption of a new process or energy-saving process that makes reduction in costs possible in the process of manufacturing products or it means adoption of a new technique that makes improvement in the quality of products possible. In addition, it is divided into a technology-push model and a demand-pull model depending on the incentive and source of technology innovation. A technology-push model is centered on.

Performance of technology innovation and research contents and functions from the standpoint of the researcher as the principal agent of technology innovation, and in the case

of the market-pull model, the possibility of generating gains stimulates needs for technological development, thereby causing technology innovation.

2.2. Innovation-type small- and medium-sized enterprises

An innovation type of SME means a corporation that has taken up technology innovation as a basic strategy, secured technological power belonging to high-added values, and shown a high level of productivity and created high profitability (Kim, 2005). An innovation type of SME means the one with technological capability, investments in technology innovation and their performance on a level relatively higher than other strategic targets (Hicks and Hegde, 2005; Yam *et al.*, 2004). In Korea, an innovative corperation is used in combination with similar terms such as innovative SMEs, Inno-biz and technology-based SMEs (Kim, 2005). However, on a closer examination of the definition of the terms made by preceding studies, an innovative SME means a small- and medium-sized enterprise having performance of technology innovation on the level of output, and Inno-biz and technology-based SME refers to an enterprise that has secured a relatively superior technological capability on the level of input. That is, while those enterprises are similar in concept in terms of enterprises having technology innovation as a managerial strategy, they differ on the level of input and output.

First, aware of the needs for technology innovation, they seek to acquire necessary information and resources. Technology, knowhow, capability and so forth an enterprise acquires are learned and stored over a long period of time, ultimately developing into the corporation's core capability (Cohen and Levinthal, 1990). The core capabilitiy is differentiated by their own resource capability because they have the value, scarcity, and imitative imperfection of the resources they hold (Kim, 2005). Therefore, innovation type of SMEs are expected to acquire resources it is lacking from outside, and to steadily seek to reduce uncertainty about efficiency of resources and investments made (Chesbrough, 2003). Chesbrough (2003) emphasized that it is highly important for an SME lacking innovative resources to adopt inbound type of open innovation in particular that creates innovation internally in the organization by using the external resources.

Second, as most of innovation types of SMEs are established in the process of commercialize technologically innovative ideas, they feature a tendency to secure a market unique to them after developing products or services on their own. Besides, innovation type of SMEs tend to depend on immaterial resources such as technology, knowhow, capability and so forth an individual has on hand, and such an immaterial resource tends to be learned and stored over a long period of time through cooperative internal R&D actions between organizations and individuals. Innovation type of SMEs have on hand an organization best suited to learning and development of new technology, and maintains close relationships with experts associated with core technology, a feature unique to this type of enterprises.

Third, innovation type of SMEs seek to adapt to technology and environment through changes in demand patterns and customer's preferences and so forth. Changes in the dynamic environment outside the company are highly risky due to high uncertainty, but they also serve as important opportunities for high profit structure. In fact, innovation type of SME's normally stand more chances of success in terms of performance of technological development, likelihood to succeed, and turning of the technological idea into a business along with a high level of management performance as a result, compared with the case of ordinary enterprises (Hong, 2010).

2.3 R&D capability and performance

The R&D of an industry is a leading activity for technology innovation, through result of which monopolistic position can be enjoyed in the market. And also, technology innovation through R&D makes organization able to satisfy the demands by the market or society by introducing new ideas for products and process technologies and commercialize by developing them (Utterback, 1971). In addition to this, it helps differentiate products and enjoy costwise predominance by enabling the development of new products and utilization of new process, and it becomes a major source of securing predominance of competition (Tidd and Bessant, 2009). Thus, the capability of R&D of industry can be defined as a dynamic capability including creation and utilization of knowledge that can strengthen the industrial ability of maintaining and acquiring predominance of the competition in the industry (Zahra and George, 2002).

Result of R&D is a proportion of output including input of human and material resources that have been invested for activities of R&D, which means efficiency or effectiveness in producing outputs with resources having economic values, such as human resource, facility, capital and time (Ranftl,1978). Result of R&D can be assorted to direct performance that can be directly obtained by an effort of R&D and to indirect performance that can be acquired through technical performance. Direct performance includes patent, number of property rights or income of technical fee, whereas indirect one includes, in narrow sense, commercialization of R&D and cost reduction, and, in wide sense, contributes to invigoration of national economy and enhancement of national competiveness.

Patent among direct performance is means for effectively protecting competitive assets including products of enterprise, process and service, which is an important yardstick for measuring the ability of technology innovation and the effect of technical competitiveness of industry. Studies on the relationship between R&D capability and patentability are very wide in their range, have been deeply conducted and appeared to generally have positive effects (Artz *et al.*, 2010; Hall and Bagchi-Sen, 2002; Hall and Ziedonis, 2001; Lin *et al.*, 2006; Reitzig and Puranam, 2009; Romijn and Albaladejo, 2002; Somaya *et al.*, 2007; Souitaris, 2002).

Romijn and Albaladejo (2002), in their study on 33 of small enterprises related to electronics and software in southeastern district of England, proved that the capabilities of R&D has a correlation with the performance. The capabilities of R&D are investment amount per individual, investment ratio for R&D to sales, ratio of human resource for R&D to number of employees and the performance is products innovation, number of patent and indicator of products innovation. In addition, internal exertion for R&D is one of the activities of enterprise and important source of innovation was emphasized. Along with it, they emphasized that acquiring and using external R&D resources from customers, universities and public institutions are necessary to complement insufficient internal R&D resources of small industries.

On the other hand, in some studies, R&D has no direct relation with innovativeness (Birchall *et al.*, 1996; Kwon and Lee, 2004), or there were also some studies that showed different effects according to the kind and characteristics of industry or according to the type of innovation, such as product innovation or process innovation (Hall and Bagchi-Sen, 2002). Another study showed reverse result according to explanatory factor (Kim and Yoon, 2009). Therefore, this study aims to empirically analyze the effect of R&D capabilities of innovative SMEs on patent performance, and to compare the results with those of previous research.

Product development among indirect results means commercialization of new technologies developed through the activities of R&D. In new product development,

technical capability and human resources that enterprises are presently possessed of are important factors for securing competitiveness (Cooper, 1979; Ernst and Fischer, 2014; Gresham *et al.*, 2006; Löfsten, 2016, Nerker and Roberts, 2004; Pernner-Hahn and Shaver, 2005).

Dutta *et al.* (1999) conducted study on the relation between technology innovativeness of new products capability of R&D including range of application of technology, human resource for study, and cost for R&D, and as a result of analysis, capability of R&D has positive effect on performances related to development of new products. They picked two kinds of reason that the capability of R&D acts as an important factor. First, launching of new products furnished with prominent innovative function in market enables securing consumers with high loyalty, and finding merit in the aspect of creation of profit and demand as relevant consumers belong to the group that has an intention to pay additional cost over the price for products of enterprise. Second, capability of R&D may be connected to competitiveness in the factor of supply side, and Japanese enterprises such as Sony and Hitachi could dominate new market by adopting cost structure favorable to themselves based on prominent process innovation ability. Continuous securing of competitiveness in the market is possible by development of new technologies based on excellent technical skills at the same time by cost reduction through process innovation.

3. Research question and model

In this study, research model and research questions were set up as the following to analyze the effect of the capability of R&D on the result of new products based on preceding studies on technical innovativeness, factor and result.

RQ1. What relation exists between the capability of R&D of innovation-type SMEs and patentability?

RQ2. What relation exists between the capability of R&D of innovation-type SMEs and developing character for new products?

Concretely, capability of R&D of innovation-type SMEs, an independent factor, was measured by an investment amount for R&D by enterprise and the number of human resources for R&D. Investment amount for R&D includes external R&D investment amount as well as internal one. As innovation-type SMEs have characteristics of accumulating core capability by acquiring and learning resources for open innovation, external R&D investment amount is also one of the important elements (Figure 1).

The number of human resources for R&D was departmentalized into the number of concentrations of R&D human resource, the number of cooperations of R&D human resource and the number of foreign human resources.

Performance factor was divided into result of patent as direct performance and result of new product development as indirect performance. In patent result, effectiveness of capability of

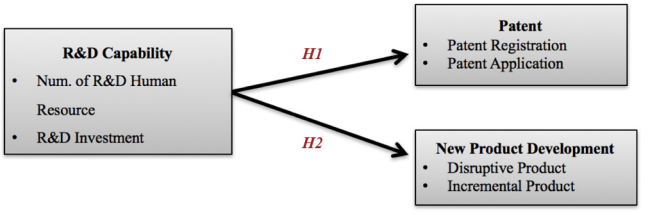


Figure 1.
Research model

R&D was going to be confirmed by measuring the patent application for past three years and the number of registered patents. Generally, patent result can be distinguished between the number of patent registrations and the application at large, because the patent that only contains technical element can be registered (Pavitt, 1998). In addition, development result of new product was measured depending on whether radical new products have been launched or whether gradually improved products have been launched over the past three years.

Finally, as these variables may be affected by scale of firm (sale amount), the scale of firm was used as control variables (Table I).

4. Methodology

4.1 Data

This study was conducted by using raw data as a centered object from the "survey on activity of technical innovation of 2010" surveyed by STEPI. In the "survey on activity of technical innovation of 2010," sample survey was conducted targeting enterprises and 41,485 business firms according to the "survey on national business firms of 2008 by Office of Statistics" and final sample firms were selected by the method of random sampling using sampling method of Neyman by kind of business and scale level of employees for representability of the population.

The period of survey was from May to October 2010 and a total of 3,925 samples were obtained. In this study, information from effective data of total 834 venture businesses, innovative small enterprises and Inno-biz enterprises was used for final analysis.

4.2 Methodology and equation

For data analysis, STATA 12.1, a statistic package program, was used, and samples with phrase for null value or outlier removed in advance were used. To look into the general

Variable	Definition
Dependent variable	
Patent	
Patent registration	Number of patent registrations (2009)
Patent application	Number of patent applications over the past 3 years (Yes:1/No:0)
New product development	
Disruptive products	Launching of new products for past 3 years (Yes:1/No:0)
Incremental products	Launching of improved products for past 3 years (Yes: 1/No: 0)
Independent variable	
R&D capability	
Concentration of R&D human resource (R&D TYPEA)	Number of concentrations of R&D human resource (average 2007-2009)
Cooperation of R&D human resource (R&D TYPEB)	Number of cooperation of R&D human resource (average 2007-2009)
Foreign worker (F_EMPLOYEE)	Number of foreign employees (average for 2007-2009)
Internal R&D investment (R&DCOST_IN)	Activity cost for internal R&D (average for 2007-2009)
External R&D investment (R&DCOST_OUT)	Activity cost for external R&D (average for period of 2007-2009)
Control variable	
Firm size	
SALES	Sale amount of firm (average for period of 2007-2009)

Table I. Operational definition

characteristics, patentability and basic characteristics of the result of new product development of targeted samples for survey, technical statistical analysis was conducted on the frequency and average.

Verification of research model was performed with the methods of logistic analysis and Tobit analysis. Logistic analysis is used when dependent variable appears to be 0 or 1. In this study, the capability of R&D was performed for calculating estimated model aginst probability of new product development and probability of patent application.

$$\mathrm{P_i} = \mathrm{E(Y = 1/X_i)} = \frac{1}{1 + \mathrm{e}^{-\left(\beta_{0+} \sum \beta_i \mathrm{X_i} + \varepsilon_i\right)}} \tag{1}$$

$\boldsymbol{P_i}$ = probability of new product development, probability of patent application.

In addition, on the basis of the estimated calculation by equation (1), marginal effect by items of independent factors was estimated:

$$\frac{\partial P}{\partial X_{\mathbf{i}}} = \beta_i \cdot \frac{e^{\beta_0 + \sum \beta_i X_i}}{\left(1 + e^{\beta_o + \sum \beta_i X_i}\right)^2} \tag{2}$$

And, Tobit analysis was conducted to estimate desire or potential of patent registration of firm. The Tobit model represents a regression model in which the dependent variable is observed in only some of the ranges.

$Y_{\mathbf{i}}^*$ is desired or potential of patent registration, which is denoted by:

$$\mathrm{Y_i^*} = \beta_0 + \beta_{\mathrm{i}} \mathrm{X_i} + \mu_{\mathrm{i}} \tag{3-1}$$

where X_i is the explanatory variable and μ_i indicates all the unobservable variables.

Thus, we can rewrite equation (3-1) as:

$$\boldsymbol{Y_{\mathbf{i}} = Y_i^* \quad if \ Y_i^* > 0} \tag{3-1-1}$$

$$\boldsymbol{Y_{\mathbf{i}} = 0 \quad if \ Y_i^* \leq 0} \tag{3-1-2}$$

where $\boldsymbol{Y_i}$ is observed if potential of patent registration is greater than zero ($Y_i^* > 0$), and Y_i^* is unobserved if potential of patent registration is less than zero ($Y_i^* \leq 0$).

With limited dependent variables, Maddala (1983) noted three mean marginal effect in the Type I Tobit model.

Total mean marginal effect for overall samples was noted. Equation (4-1) indicates marginal effect against overall samples and means amount of change per unit according to increase of units:

$$\frac{\partial \boldsymbol{E}(\boldsymbol{y})}{\partial \boldsymbol{X_i}} = \varnothing(\boldsymbol{z})\boldsymbol{\beta_j} \tag{4-1}$$

Mean marginal effect for latent variable and desired patent registrations was noted. It indicates tendency or latent ability rather than explaining practical value.

$$\frac{\partial \boldsymbol{E}(\boldsymbol{y})}{\partial \boldsymbol{X_i}} = \boldsymbol{\beta_j} \tag{4-2}$$

Mean marginal effect for dependent variable exceeding 0 indicates marginal effect per unit of independent variable.

$$\frac{\partial E(y/y^* > 0)}{\partial X_i} = \beta_j \left[1 - z \cdot \left(\frac{\varnothing(z)}{\varnothing(z)} \right) - \left(\frac{\varnothing(z)}{\varnothing(z)} \right)^2 \right] \quad (4\text{-}3)$$

5. Results

5.1 Characteristics of the sample

As a result of analysis on general present condition of 834 effective samples used for this study, importance of small industry appeared to occupy 99.04 per cent. As a result of analysis on development performance of new product development of targeted firms, enterprises that had developed new products for the past three years occupied 33.89 per cent and those who had launched improved products appeared to be 70.12 per cent. Such result attributes to higher difficulty of innovative products development than that of improve products. In addition, enterprises conducting patent application activity occupy 57.43 per cent, which appears to have more importance than those who do not and the number of registered patents appeared 7.54.

As a result of the analysis on the capability of R&D of enterprise, firms that replied that they are performing internal innovative activity occupied 92.09 per cent and those who answered that they are doing external innovative activity were 36.21 per cent. Furthermore, average investment amount for internal R&D for the past three years was ₩1,217m, which appeared about ₩10m more than the average of ₩180m for investment amount into external R&D, and this indicates that activity by targeted enterprise for R&D has been taken with capacity concentrated on internal innovative activity.

As a result of observation on human resource constitution for R&D, the average number of concentrations of R&D human resource appeared 7.9 persons, whereas the average number of cooperation of R&D human resource appeared 1.1 persons. This can be judged as high awareness of importance of human resource for R&D of the targeted enterprises.

Table II shows the result of general characteristics of surveyed innovation-type SMEs.

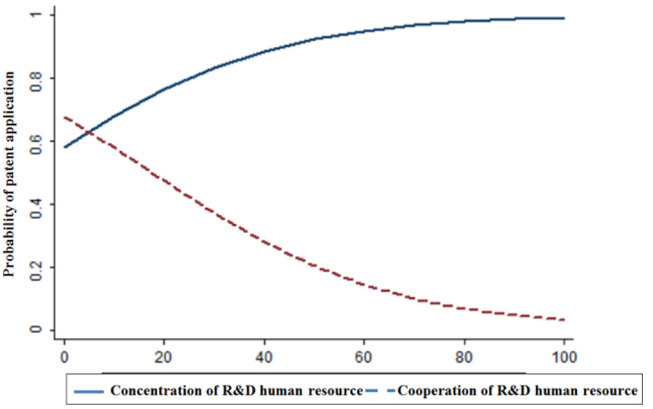
5.2 Patent registration

Result of logistic analysis on probability of patent application by innovation-type SMEs showed that the number of concentrations of R&D human resource, investment amount for external R&D and sale amount have significant effect on patent application. Additional analysis on marginal effect was conducted to comprehend detailed influential degree.

The result of analysis on marginal effect showed that, as the number of concentrations of R&D human resource increases by 1 unit (number of "person"), the probability of application increases by 0.95 per cent, whereas as the number of cooperation of R&D human resource increases by 1 unit (number of "person"), the application probability decreases by 0.94 per cent. Such study result can be interpreted that the number of concentrations of R&D human resource is an important resource in innovative-type SMEs for the creation of innovative performance. As a result of additional simulation analysis on the number of R&D human resources and on the probability change for patent application, importance of the number of concentrations of R&D human resource could be confirmed (Figure 2).

Category		*N*	%
Sales (as of end of 2009)		₩23.2bn ₩52.92m (S.D. = 43,851.19)	
Disruptive product development: During last 3 years (2007-2009)	Y	262	33.89
	N	511	66.11
Incremental product development: During last 3 years (2007-2009)	Y	542	70.12
	N	231	29.88
Internal R&D activity	Y	768	92.09
	N	66	7.91
External R&D activity	Y	302	36.21
	N	532	63.79
Internal R&D investment: During last 3 years (2007-2009)		₩1.217bn (S.D.= 3,295)	
External R&D investment: During last 3 years (2007-2009)		₩180m (S.D.= 673)	
Number of workers (at the end of 2009)		82.26 persons (S.D.=95.76)	
Number of concentrations of R&D human resource		7.9 persons (S.D.=13.09)	
Number of cooperation of R&D human resource		1.1 persons (S.D.=4.04)	
Number of patent applications		7.54 applications (S.D.=19.38)	
Patent registration: During last 3 years (2007-2009)	Y	479	57.43
	N	355	42.57
Total		834	100

Table II.
Characteristics of sample firms



Notes: *Probability of patent application has high probability as nearing to1; **Invested value for patent application (average value): the number of foreign human resources 0.0245, investment amount for internal R&D 1,217.8409, investment amount for external R&D 180.3236 and scale of enterprise 24,395.765

Figure 2.
Simulation for patent application up to R&D human resource

Furthermore, it showed that investment amount for external R&D increases by 1 unit (million Won), application probability increases by 0.03 per cent, but the effect of investment amount for internal R&D was not very significant. Thus, it can be assumed that open innovation takes higher contribution for the creation of effectiveness than internally oriented innovation in innovation activity of an innovative small enterprise.

Finally, it is shown that the smaller the scale of firm becomes, the higher probability of patent application appears (Table III).

5.3 Patent application

Tobit analysis on the number of patent applications by innovative small enterprises indicated that significant influence was shown by scale of concentration of R&D human resource, foreign human resource and investment amount for external R&D. As co-efficient value of Tobit analysis does not indicate practical value but indicates tendency and latent skill, additional analysis on marginal effect was conducted to explain the influential degree of variable.

As a result, it showed that, as the number of concentrations of R&D human resource increased by 1 unit ("person"), the number of registered patents increased by 0.2807. The case of analysis on samples with number of registered patents over 0 showed an increase by 0.0076. In the case of investment amount for external R&D, the number of registered patents increased by 0.002 every 1 unit ("million Won") out of the entire samples, in the case of samples over 0, 0.00005 increased. The variable affecting the number of registered patents is the number of foreign human resource, which showed as 1 unit increased out of overall samples, the number of registered patents increased by 5.7142, whereas, in the samples over 0, increase by 0.1248 was shown.

Result of Table IV supports the importance of human resource for R&D and open innovation similarly to the probability of patent application shown in Table III. But, in the case of enterprise scale, the bigger the enterprise scale becomes, the more increase the number of registered patents makes, which indicates that the effectiveness of patent application emerges in larger-scaled enterprises.

5.4 New product development

As a result of the logistic analysis on the effect that affects launching of innovative product (disruptive product) and improved product (incremental product), result shown in Table V was deduced. Model 1 is the performance from launching of innovative product and Model 2 is that from improved product.

Model 1 indicates that as the number of concentrations of R&D human resource increased by 1 unit ("person"), probability of launching innovative product increased by 0.41 per cent.

Model 2 shows the number of concentrations of R&D human resource and investment amount for external R&D have significant effect on launching of improved products. Concretely speaking, probability of launching improved products increases by 0.7 per cent

Variable	Coefficient	Std. Err.	$\partial P/\partial X_i$	z	p-value
R&D_COST_IN	0.0427***	0.0120	0.0095	3.55	0.000***
R&D_COST_OUT	−0.0421*	0.0206	−0.0094	−2.04	0.041*
R&D_TYPEA	0.4507	0.6031	0.1005	0.75	0.455
R&D_TYPEB	0.00005	0.00005	0.0000	0.97	0.333
FEMPLOYEE	0.0015**	0.0004	0.0003	3.15	0.002**
SALES	−4.16e-06*	1.95e-06	−0.0000	−2.14	0.033*
CONSTANT	0.1161	0.0989		1.17	0.241
Log likelihood	−479.2167				

Notes: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table III.
Probability of patent registration

when the number of concentrations of R&D human resource increases by 1 unit ("person") and by 0.01 per cent every time the investment amount for external R&D increase by 1 unit ("million Won"). In relation with result of new product development, as study examples with special designation of launching of improved products as dependent variable are seldom to find, grafting of this analysis result with existing studies is difficult, but the argument that when taking gradual improvement of products as result of new product development in comprehensive aspect, capability of R&D may have positive effect on performance of new products. Cooper (1979), Dutta *et al.* (1999) and Freel (2003) had the same directional nature with existing studies.

A simulation analysis was tried to observe the effect of the number of human resources for R&D on the launching probability for innovative products and improved products. Result of the simulation is shown in Figure 3.

6. Conclusion

This study was conducted to analyze the relation of effect that the capability of innovation-type SMEs has on patentability and development of new products. To attain the object of such study, study model and research questions were constituted with consideration of local

Variable	Coefficient (S.E)	$\frac{\partial E(y^*)}{\partial X_i}$	$\frac{\partial E(y)}{\partial X_i}$	$\frac{\partial E(y/y^* > 0)}{\partial X_i}$	t
R&D_COST_IN	0.4920*** (0.0676)	0.3876	0.2807	0.0067	7.28
R&D_COST_OUT	0.1451 (0.1872)	0.1143	0.0828	0.0019	0.78
R&D_TYPEA	9.0687* (4.0121)	7.1447	5.7141	0.1248	2.26
R&D_TYPEB	0.0002 (0.0002)	0.0002	0.0001	3.851e-06	1.11
FEMPLOYEE	0.0036** (0.0011)	0.00286	0.0020	0.00005	3.08
SALES	0.00005** (0.00001)	0.000042	0.000030	7.361e-07	2.87
CONSTANT	−2.3434 (0.9940)				−2.36
Sigma	21.05 (0.6117)				
Log likelihood	−2836.256				
$N = 773$	609 uncensored observations 164 left-censored, Num_Patents < = 0				

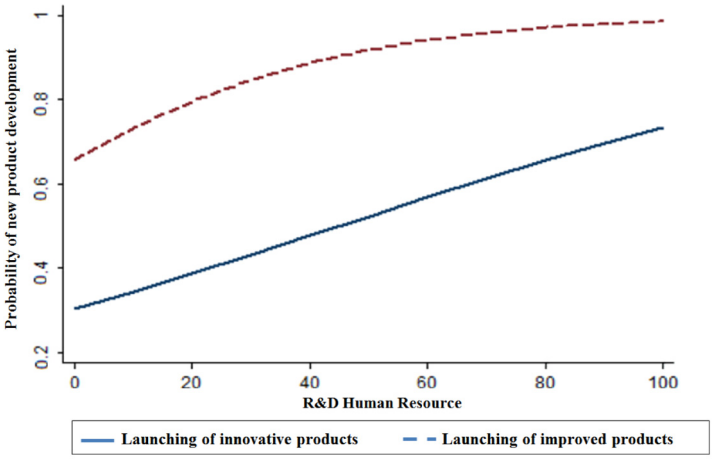
Notes: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table IV.
The number of patent applications

Variable	Model 1 Coefficient (S.E)	Model 1 $\partial P/\partial X_i$	Model 2 Coefficient (S.E)	Model 2 $\partial P/\partial X_i$
R&D_COST_IN	0.0184** (0.0069)	0.0041	0.0342** (0.0113)	0.007
R&D_COST_OUT	−0.0032 (0.0182)	−0.0007	0.0003 (0.0325)	0.00006
R&D_TYPEA	0.8871 (0.4671)	0.1982	Omitted	
R&D_TYPEB	−4.66e-06 (0.00002)	−1.04e-06	−0.00004 (0.00003)	−8.79e-06
FEMPLOYEE	0.0002 (0.0001)	0.00005	0.0007* (0.0003)	0.0001
SALES	−2.43e-06 (2.25e-06)	−5.43e-07	−1.21e-07 (2.30e-06)	−2.47e-08
CONSTANT	−0.8291*** (0.0971)		0.5435*** (0.1056)	
Log likelihood	−484.4711		−451.3753	

Notes: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table V.
New product development performance



Notes: *Probability value will be higher when near to 1; **Input value (average value) for simulation of patent application: number of human resources for R&D: number of exclusive human resources for R&D 1.2043 persons: number of foreign human resources 0.0245 persons, investment amount for internal R&D 1,217.8409, investment amount for external R&D 180.3236 and scale of enterprise 24,395.765

Figure 3. Simulation of new products development up to human resource for R&D

and foreign study literatures, and empirical analysis was conducted using data from survey on technical innovation of 2010 done by STEPI to verify this.

Different from most of the local study results (Park and Kim, 1989; Kim and Choi, 2001; Kang and Lee, 2006) that regard performances of patent and new products development as separate innovation result, this study has some differentiation from existing study result in which the results of patent and new products had been analyzed using a single study frame.

This study can be summarized as following:

First, the study capability of innovation-type SMEs has been concentrated on the field that affects direct profit such as the numbers of registered patents. In addition, the effects that have direct relation with new products through products innovation such as quality improvement of products and expansion of market share appeared big, whereas the effects in the fields that have no relation with new products such as attainment of standard of industrial technology and addressing to local and foreign regulations appeared small. Such phenomenon can be judged due to the concentration of capability of R&D on creation of profit more direct than subsidiary effect of new products in the characteristic of small enterprise that should retrieve the investment made for innovation within short period of time.

Second, the number of human resources for R&D, investment amount for R&D and scale of enterprise appeared to have positive effect on result of patent. Such study result shows that an increase in study on investment for R&D will promote result of patent (Griliches *et al.*, 1991) that conforms to past study result. In addition, marginal effect of the number of concentrations of R&D human resource in relation to patent application and patentability showed 0.0094 of positive (+) effect, whereas marginal effect of the number of cooperation of R&D human resource has negative (−) effect, which evidences importance of the number concentration of R&D human resource. Accordingly, to attain result of innovation related to

patent, innovative small enterprises will need securing professional human resource for R&D that can contribute to practical R&D.

Third, result of new products development was analyzed being divided into developments of innovative new products and gradual new products. Such study result supports past study result that the capability of R&D has a positive effect on the result of new products (Cooper, 1979; Dutta *et al.*, 1999; Freel, 2003). As a result of empirical analysis, marginal effect of the number of concentrations of R&D human resource appeared 0.00042 in the analysis on launching of innovative products, whereas that on launching of improved products appeared 0.007, which was analyzed to show bigger effect in improved products when the number of concentrations of R&D human resource has the same unit. Such phenomenon attributes to bigger difficulty of developing innovative products that the developing improved products.

In addition, marginal effect of result of new products development (launching of innovative products: 0.0042, launching of improved products: 0.007) appeared lower than patentability of the number of concentrations of R&D human resource and marginal effect (number of registered patents: 0.2807, patent application: 0.0095), and such result shows reverse aspect against characteristic of small enterprises that have the tendency of concentrating on R&D for developing new products. In the case of the result of development of new products, measuring of result of R&D was set for three years as criterion, but, in the case of number of registered patents, time is not estimated to have not been set. In case of comparing these two dependent variables afterward, conduct of precise analysis is needed after matching the duration using count data model.

Human resource for R&D and investment amount for external R&D showed statistically significant result. Especially, the number of concentrations of R&D human resource has very important effect on the result of new product development, which empirically supported market demand for expansion of the number of concentrations of R&D human resource for innovative small enterprises. This can also be confirmed through simulation.

On the basis of this study, following points are proposed. Patent activity related to new products is an important element for innovative small enterprises, but the area of patent activity also needs to be invigorated for including sale of patent right that is a factor for creating added profit from patent or reducing cost. In addition, investment for R&D in the area of process innovation and innovation of organization/marketing that can develop future market and create profits in view of long-term insight seems to be necessary. This result shows, in the case of marketing innovation, the fact that the number of human resources for R&D has negative (−) relation with big enterprise, whereas it shows positive (+) relation with small enterprises. It shares the same context with the study by Lee (2012). In other words, especially the number of concentrations of R&D human resource among capabilities of R&D of small enterprises has close relation with innovation result of enterprise, which implies to also have important relation with management result including innovation result of enterprises.

In addition, as per the result, innovative small enterprises need to secure the number of concentrations of R&D human resource for maintaining sustainable competitiveness and securing market share. Therefore, establishment of strategy is needed that enables using and raising excellent human resource in the quantitative and qualitative aspects. However, in the circumstances that small enterprises relatively suffer difficulty of securing professional human resource for R&D compared to big enterprises, as limit exists for securing only human resource for R&D from the dimension of enterprises, governmental political support is thought to be necessary to secure human resource of good quality for R&D. Accordingly, result of this study provides many implications to the necessity of detailed methodology on how to expand professional human resource for R&D among

supporting policies for technical innovative enterprises as well as establishment of innovative strategy of enterprises.

As this research was based on secondary data, this paper had limitation to apply various variables into the model. In addition, the research hypothesized that SMEs have similar characters, but practically innovation-type SMEs need to consider various internal and external characters including core technology, entrepreneurship and market condition. In future research, these limitation points will be covered by adding these data to the primary data

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