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The impact of efficiency parameters on firms' innovative activities: Evidence from Korean firm-level data*

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Abstract

With the premise that patent data are reliable indicators of innovativeness, the empirical analysis of R&D–patents relationship is useful for monitoring the efficiency of the innovation process. This paper extends the research on the relationship between R&D spending and patent counts by estimating the impact of efficiency parameters. A data set from 1255 firms with nonzero R&D expenditures in Korea was studied. Results show that the difference in firms' innovative performance is attributable to firm-specific characteristics, including propensity to patent and firm size, and differences in efficiency parameters. They also indicate that firms that conduct patent searches before starting R&D activities obtain an average of 13.9% more patents with an increase of one unit on the 'patent search' scale. Results also show the importance of the role of IP managers and revenue splitting policy for employee-inventors in the innovation process.

Key words: Incentive for employee-inventor, Innovation process, Innovative performance, IP manager, Preliminary patent search, R&D–patents relationship

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1. Introduction

The term “knowledge-based economy” stemmed from the growing recognition of the importance of knowledge in a global economy. That is, economic growth, wealth creation, and employment across all industries are more heavily dependent on the production, distribution, and use of knowledge than ever before (Asian-Pacific Economic Cooperation [APEC] 2000; Organisation for Economic Co-operation and Development [OECD] 1996).

Notably, the reliance on knowledge is strengthened with the existence of the patent system, which provides an exclusive property right to monopolize and utilize knowledge. Many nations and firms are willing to invest huge amounts of labor and capital to secure competitive patents. Therefore, the upswing in worldwide filings of patent applications is unsurprising. This trend is accompanied with increases in R&D expenditures, which are considered to constitute a driving force behind the increased patent applications. The average annual rate of increase in worldwide patent filings since 1995 is 4.7%, which is fairly comparable to the overall increase in R&D expenditures over the same period (World Intellectual Property Organization [WIPO] 2007).

However, the recent surge in patent applications observed in several countries does not appear to be a general rule. The number of domestic patent applications in several countries rose substantially, but R&D expenditures in those countries grew only modestly (Blind et al. 2006). In the 1980s through the early 1990s, the United States and Japan exemplified the discrepancy between the levels of patent filings and R&D expenditures; currently, South Korea and China show a similar discrepancy between R&D and patent applications.¹ A number of researchers have tried to present hypotheses to explain the phenomenon (e.g., Kortum & Lerner 1999; Kim & Marschke 2004; Hu & Jefferson 2008) and, particularly for public policy, it is still important issue to ascertain the forces behind the recent surge in the patenting applications.

In the current paper, we exclusively address the issue at the firm level. A strong positive correlation exists between patent applications and R&D expenditures of firms. But firms, as is the case for nations, have quite different patent intensity (as measured by the number of patent applications per R&D expenditures). Therefore, we ask two main questions: What are the main sources of heterogeneity in firms’ innovative performances? And can they be changed or improved by a firm’s investment or government support in a relatively short period?

This paper extends the research on the relationship between R&D and patents. Our objective is to identify the factors associated with efficiency of the innovation process and to estimate empirically the impact of these factors on firms’ innovative performances in terms of patents. To achieve this, we define preliminary patent search, exertion of intellectual property (IP) managers, and incentive for employee-inventors as efficiency parameters. Using a data set from 1,255 firms with nonzero R&D expenditures (including 727 firms with nonzero patents) in Korea, we estimate the impact of efficiency parameters and test three hypotheses about the impact of efficiency

¹ International patent intensity (triadic patent families divided by industry-financed R&D) rose significantly in Korea since the mid-1990s, owing to the more rapid growth in patenting than in R&D expenditures (OECD 2007).

parameters on firms' innovative activities and widely-accepted facts about the R&D–patents relationship.

The rest of the paper is organized into four sections. In the first, we present our review of previous literature on the input-output relationship between R&D investment and patent counts, and we discuss the distinguishing feature of this study. Second, we present the hypotheses used in this study, and describe the data and estimation model used. In the next section, we offer the main findings gained through the estimation model. Finally, we conclude with a discussion of the policy implications of the findings.

2. Efficiency parameter, firm size and the propensity to patent

Efficiency parameter and the R&D-patent relationship

Farrell (1957) explained that technical efficiency is a firm's capacity to get maximum production by utilizing specific production factors as effectively as possible. In fact, the effective use of production factors became a basic measurement among those in all economics disciplines. In particular, R&D investment is recognized as a leading indicator to predict future competitiveness. Therefore, efficient use of R&D investment, coupled with quantitative increases in R&D investment, has become a decisive factor to determine firm or national future competitiveness.

To measure the efficiency of R&D investment, various output indicators can be defined. Private firm can define them as productivity growth rates or new product announcements. The public sector players, including universities, often define them as licensing performance or the number of published papers. In spite of the substantial variety of innovation output indicators, we use patent counts as indicators of innovation output, and we review the literature focusing on input-output relationship between R&D investment and patent counts because it is a well-known topic among those empirically analyzing the efficiency of the innovation process (Beneito 2006).²

Patent data have been and still are the most frequently used as a resource for studies on technological change and innovation (Griliches 1990). After Schmookler (1966), who is regarded as a pioneer in the use of patent data, many researchers have employed patent data of countries, industry sectors, technologies, or firms in their studies. Empirical studies that are focused on the R&D–patent relationship are leading examples. Many researchers have shown a positive relationship between patent applications and R&D expenditures by setting time lags in their research (see Bound et al. 1984; Hausman et al. 1984; Hall et al. 1986; Jaffe 1986; Vermeulen et al. 2003).

Not surprisingly, patent counts as innovative output are not solely explained by R&D expenditures. Many other factors affect the R&D–patents relationship. The number of patent applications per R&D expenditures (patent intensity) differs among firms and among nations, and they are changing periodically as well. Such discrepancies or changes are influenced by external factors such as alterations in patent policy and the legal environment. Also, a firm's internal factors such as innovation history, location and

² On the other hand, a notable weakness of patent counts as a measure of innovative output may suggest that it is not suitable for assessing the R&D–patents relationship or subsequently as a means of measuring efficiency of innovation process. These issues will be addressed in final section.

technological diversification are important as sources of heterogeneity in innovative performance. So, by connecting R&D spending and patent counts, we can better understand the innovation process in which an output is created from R&D investment.

In this context, researchers have considered the factors that may affect innovative performance as important explanatory variables in their patent production functions. For example, Cincera (1997) investigated not only R&D spending but also technological spillover as well as geographic and technological opportunities as determinants of patenting. Jozefowicz (1999) analyzed the impact of current and lagged R&D spending, intra-sector R&D spillover, patent count spillover, and firm size. Kortum and Lerner (2000) assessed the contribution of venture capital to firms' patent applications. Hall and Ziedonis (2001) analyzed the patenting behavior of U.S. semiconductor firms and found the series of pro-patent legislative changes led to patent portfolio races. Garcia (2006) showed that patents increase with the degree of technological diversification of the firm using panel data of European R&D active companies. Han and Lee (2007) examined the influence of firm characteristics such as export share, degree of foreign ownership, and corporate structure (e.g., Chaebol-affiliation) by using a data set comprised of Korean firms.

Previous empirical studies have offered valuable information about factors affecting the R&D–patents relationship, but many variables used in these studies are difficult things to improve or change in a short period. Therefore, a focus on factors which are under a firm's control may be a better approach for analyzing innovation process, especially when they are geared to improving innovation efficiency. For example, the wide use of patent information in planning R&D projects can do much to improve the efficiency of R&D expenditures in many ways. Also IP managers can assist in overcoming many obstacles encountered in innovation process. An incentive system for employee-inventors that encourages employee's patenting activity can make efficient use of R&D expenditures. We define these factors as “efficiency parameters” and use them in building an estimation model.

Efficiency parameters can yield much information and policy implications because they can be changed or improved by a firm's investment or government support in a relatively short period. Unfortunately, however, it seems that empirical studies using variables related to these items are scarce. The distinguishing feature of this study is the use of efficiency parameters in overcoming limitations encountered in many previous studies and an extension of information on the R&D–patents relationship.

Firm size and the propensity to patent

The number of patents as a measure of innovative output is affected by firm size and propensity to patent. The notion that a large firm would have a broad R&D scale and a relatively high propensity to patent compared to smaller companies is intuitive (see Scherer 1965; Panzar & Willig 1981; Cohen & Klepper 1996; Brouwer & Kleinknecht 1999).

In this context, we need to note that the propensity to patent is not homogeneous. Depending on the type of innovation, industrial sector, and firm size, securing a patent may or may not be a more effective means of protecting profits than other tactics such

as secrecy, lead time, know-how, and so forth. In fact, the results from surveys of U.S. firms, which were conducted to find out how these companies appropriate innovation and prevent unauthorized use of it, showed that patent protection is not the most effective means and firms often prefer secrecy for protecting process innovations (see Yale Survey 1987; Carnegie Mellon Survey 1994).

Also, the results of the *Community Innovation Survey–Netherlands* (CIS) and the *Korean Innovation Survey* showed that secrecy or lead-time advantage are preferred more for protecting appropriations of process innovation than for protecting product innovation, especially in the service sector. Therefore, deviation between a firm's R&D input and its patent intensity may be more or less attributable to efficient use of R&D inputs rather to differences in the propensity to patent (Brouwer & Kleinknecht 1999). So, to separate empirically two different reasons, we define proxy measure of firms' propensity to patent and use it as control variable with other characteristics such as firm size and industrial sector. Arora et al. (2008) defined patent propensity as the percentage of the business unit's product innovations for which patent protection is sought. They also showed a positive relationship between patent effectiveness and patent propensity. In this study, we use filing preferences as proxy measures for propensity to patent. The filing preferences data reflect a firm's judgment about the effectiveness of the patent for innovation protection.

Additionally, R&D expenditures in small firms may be undercounted (Kleinknecht 1987; Pavitt & Patel 1988). If undercounting problem of R&D in small firms is serious, patent intensity is systemically biased by firm or R&D size. So, in this study we divided the samples into two groups: those with R&D spending greater than US\$500,000 and those with nonzero R&D expenditures (all firms).

As a result, this study allows better understanding of the association between innovative performance and innovation process. Also problems arising from use of patent counts are limited in our empirical model.

3. Hypotheses and estimation model

The wide use of patent information in planning and managing R&D projects can greatly improve the efficiency of the innovation process. By analyzing patent information before starting R&D project, firms can vastly widen comprehension of the field of invention and avoid wasteful duplication of R&D projects. Hence, the delicate conduct of preliminary patent searches can play a vital role for efficient innovation processes and contribute to successful R&D management.

Also IP managers can positively affect the firm's innovation process in many ways. The traditional role of IP managers in firms involves writing and filing the initial patent application and managing patents to support R&D activities. However, as the importance of the overall IP strategy is increased, IP managers are increasingly and more deeply involved in planning and managing R&D projects. For example, IP managers find patentable inventions and support decision-making processes in R&D activities. Also, IP managers detect competitors' existing patents that could interfere with the firm's R&D. IP managers encountering such circumstance can direct the firm's R&D activity to a design-around patent, saving the firm huge R&D expenditures and ensuring an effective

patent. In other circumstances, IP managers can set guidelines for disclosing inventions made in the firm or for joint inventions made with outsiders. Without such guidelines, companies may inadvertently disclose an invention in a manner such that the novelty, a core requirement for patentability, is gone.

The employee-friendly incentive system to encourage employees' patenting activity can contribute to efficient use of R&D expenditures. Many studies on the relationship between incentives and performance underscore the importance of incentives to economic efficiency. Incentives commonly induce better performance by reducing the agent's moral hazard; the greater the incentive, the greater its effect (see Ke et al. 1999; Chang et al. 2003; Ryu 2005). Likewise, incentives regarding innovation can generate efficient use of R&D expenditures.

We propose the following three hypotheses about the impact of efficiency parameters in firms' innovative activities:

The innovative performance of a firm's R&D in terms of patents is, *ceteris paribus*, higher than other firms if the firm

H1. conducts preliminary in-depth patent searches before starting R&D activities.

H2. has a strong employee-friendly incentive policy to encourage employee patenting or innovation activity.

H3. has a significant number of IP managers who support the decision-making processes in R&D and innovation activities.

After Schumpeter's claims about the advantage of large firm in innovative activity, many studies were focused on the relationship between firm size and some measure of innovative inputs or outputs. The positive relationship between R&D spending or patent counts and firm size has been interpreted as supporting the Schumpeterian hypothesis (Cohen and Klepper 1996). However, some researchers have tested the Schumpeterian hypothesis using the number of patents per dollar of R&D as a measure of innovative output and have found that the patent intensity tends to decline with firm size or R&D increases.³ In other words, patent counts increase at a rate that is less than proportional to firm size (see, e.g., Bound et al. 1984; Acs & Audretsch 1991; Cohen & Klepper 1996; Kim et al. 2004). Therefore, we review widely-accepted facts about the R&D–patents relationship:

1. A strong positive correlation exists between patent counts and firm size.
2. Patent counts increase at a rate that is less than proportional to R&D expenditure or firm size; that is, patent intensity is a decreasing function of R&D expenditure or firm size.
3. The higher a firm's propensity to patent (high assessment of patent effectiveness as a means of protection for innovation), the higher patent intensity is.

Because the dependent variable is the number of patent applications, which is a "count" variable and takes nonnegative integer values, the Poisson regression approach is more

³ Nevertheless, larger firms conduct more R&D than smaller firms because larger firms have the advantage of cost spreading R&D expenditures (Cohen & Klepper 1996).

appropriate for analyzing the R&D–patents relationship (Hausman et al. 1984). We assume that the expected number of patents applied is an exponential function of the firm’s R&D spending, efficiency parameters and a firm’s characteristics.

However, under the Poisson model, we must assume that the conditional mean and variance of Y_i given X_i are equal, which may be overstating the case in general and hence cause rejection of the overdispersion test (Cameron & Trivedi 1986). The presence of overdispersion causes standard errors of parameters to be underestimated, resulting in overstatement of levels of statistical significance (Baum et al. 2000). Alternative specifications of the Poisson model can be found in a negative binomial model that allows for overdispersion. For comparing fits of negative binomial and Poisson regression model, we performed a likelihood-ratio test of $\alpha = 0$ and χ^2 goodness-of-fit test.⁴ In a supplementary analysis we found overdispersion in all models we present in this paper. And the hypothesis that the data are from a population with the Poisson distribution is rejected; that is goodness-of-fit $\chi^2 > \chi^2(0.01, 1240)$. Also, as around 42 percent of firms in the sample have no patent newly filed in 2006, a zero-inflated negative binomial (ZINB) model may be more relevant.

Therefore we specified the following ZINB model and report estimates from ZINB regression models:

$$PAT_i = \exp(\beta_0 + X_{1,i}\beta_{1,1} + X_{2,i}\beta_{1,2} + X_{3,i}\beta_{1,3} + \varepsilon_i)$$

PAT_i is the number of patent applications newly filed in 2006. X_1 includes four explanatory variables related to firm-specific characteristics and X_2 includes five explanatory variables related to efficiency parameters. X_3 includes five dummy variables of the industrial sector to which the firm belongs. Table 1 provides descriptions of the explanatory variables.

- Insert [Table 1] around here -

The data used for the analysis are provided by the *Survey on Intellectual Property-Related Activities in Korea*, undertaken by the Korea Institute of Intellectual Property and Korea Intellectual Property Office (KIPO) in 2007. The main purpose of the survey is to collect information about levels and characteristics of IP-related activities of Korean firms and research organizations. The survey is conducted on firms and research organizations that exceed a specified number of patent and utility model applications in benchmark years (2004-2005). The survey is composed of four sections of questions: production of intellectual property rights (IPR), protection of IPR, use of IPR, and infrastructure related to IP activities.

For our study, a total of 1510 survey responses were collected (response rate: 38.2%), and we used a data set from 1255 firms for the analysis. The data set on patent applications in 2006 comes from the KIPO database. We provide summary statistics of the variables in Table 2.

- Insert [Table 2] around here -

⁴ There are several functional forms of heteroscedasticity according to mean-variance relationships (Cameron & Trivedi 1986). The specification of overdispersion used in this paper is given by Mccullough and Nelder (1983)

4. Empirical results

Table 3 shows descriptive figures of patent counts and patent intensity as innovative outputs. The firms obtain an average of approximately 0.41 patents per US\$100,000 of R&D expenditures. The patent intensity may or may not be affected by the undercounting of R&D in small firms, but it tends to decline with R&D increases.

- Insert [Table 3] around here -

The estimation results are presented in Table 4. Model (4) shows regression results of the group with R&D expenditures greater than US\$500,000. Model 1, 2 and 3 show regression results of the group (all firms) including firms with R&D costs less than US\$500,000. To avoid confounding the R&D effect with size effect, when we used firm size we normalized R&D spending by the number of employees.

- Insert [Table 4] around here -

The regression results of four models allow a valid assessment of our three hypotheses and widely-accepted facts about the R&D-patents relationship. As expected, both preliminary patent searches before starting R&D activities and the exertion of IP managers have a positive and statistically significant impact on firms' patenting activities. When controlling for other variables, we found that firms that conduct preliminary patent searches before starting R&D activities obtain an average of approximately 13.9% more patents with an increase of one unit on the 'patent search' scale. This result suggests that the use of patent information in planning and managing R&D projects is vital for efficient innovation processes and contributes to successful R&D management. In fact, the firm can clearly aim for inventions that meet their needs and avoid wasteful duplication of R&D project by conducting preliminary patent searches before starting R&D project.

Findings also show the importance of the role of IP managers in the innovation process. As their role has widely changed, IP managers are increasingly involved in R&D projects and assist in overcoming many difficulties encountered in the R&D process. Therefore, many firms are reinforcing their IP divisions to support the decision-making process in various IP activities and to connect their R&D activities and IP strategy effectively.

Furthermore, the estimate shows that monetary incentives provided to employee-inventors as revenues resulting from the use of the patent by employer or a third-party encourage employees' innovation activity. However, lump-sum bonus and non-monetary compensation for a patent application does not seem to have influence on a firm's innovative performance in the same way as revenue splitting does. This result suggests that firms need to review incentive policies that might improve innovative performance because few firms adopt revenue-splitting policies for employee-inventors compared with public sector players.

The similarity of the estimate reported in models 3 and 4 indicates that the undercounting problem of R&D in small firms is likely to have little effect on estimation results regarding the overall impact of efficiency parameters. Therefore, the deviation of a firm's innovative performance in terms of patents is attributable to not only firm-

specific characteristics, including propensity to patent and firm size, but also to differences in efficiency parameters affecting innovation processes.

The results of models 1 and 2 are consistent with widely-accepted facts about the R&D–patent relationship. Model 1 shows that the estimated R&D elasticity of patenting is .61, which is similar with estimates reported in previous studies (e.g., Bound et al. 1984; Hall et al. 1986; Hausman et al. 1984; Kim et al. 2004). Model 2 shows a scale coefficient of .71. Therefore, patent counts increase at a rate that is less than proportional to R&D expenditure or firm size. Namely, as generally accepted, R&D is subject to diminishing returns and patent intensity is a decreasing function of R&D or firm size.

Propensity to patent, not surprisingly, has a positive and strong impact on patent intensity. We found that for an increase of one unit on the propensity-to-patent scale, a firm is approximately 17.0% more likely to patent. Also, IP lawsuits have been very important influencing factors affecting patent intensity.

5. Conclusion and discussion

With the premise that they are reliable indicators of innovativeness, patent data may be useful in analyzing the R&D–patents relationship for the purpose of monitoring the innovation process efficiency. In this paper, we have identified factors affecting firms' innovative performances and analyzed the overall impact of them. Especially the preliminary patent search, exertion of IP managers, and incentive systems for employee-inventors can affect efficient use of a firm's R&D expenditures in many ways and they may be changed or improved in a relatively short period. So, we have defined these factors as efficiency parameters.

As shown in Table 4, the difference in efficiency parameters results in the differences in innovative performance as measured by patent applications. Although our findings on the efficiency of innovation processes are not fully conclusive, we obtain interesting insights about intra-firm factors that affect the R&D–patents relationship. This result is noteworthy because it means that investment or government support can considerably change the efficiency of the innovation process.

In Korea over recent years, the patent activity of small and medium enterprises as well as large firms has rapidly increased, and the overall patent intensity has risen significantly. The growth of firms' investment related to patenting activities, including expanded R&D expenditures, is the main force behind the increase in the number of patent applications. Because of the significance of securing competitive patents and the tendency of increase in R&D expenditures, enhancing innovative performance in terms of patents through effective use of R&D investment has become a basic goal shared by all firms. Thus, companies have tried to equip themselves with better physical capital to support efficient R&D investment.

Furthermore, governmental supports have played a major role along with firms' investment. For example, the Korean government has established several important policies related to patenting activities. The online patent-information search service launched in 1996 is representative of these wise policies. The *Korea Intellectual Property Rights Information Service* enables the general public to access patent

information easily for countries such as Korea, Japan, and the United States. Also, since 2005, to avoid wasteful duplication of R&D projects, the Korean government has mandated that patent information be analyzed before mid- and long-term R&D projects supported by government funds are initiated. Korea has continued to make progress toward encouraging employee-inventor innovation by addressing legal issues associated with it.

However many areas are yet to be improved to enhance the efficiency of R&D investment. For instance, according to the *Survey on Intellectual Property-Related Activities in Korea*, 46.2% of firms in Korea do not conduct preliminary patent searches before starting their R&D activities. Furthermore, less than 25.0% of firms have at least one IP manager to support decision-making processes in various IP activities. Also only 16.0% of firms surveyed provided monetary incentives to employee-inventors as calculated by revenues generated by their inventions. Although Korean firms that have adopted employee-friendly incentive policies have recently increased, this figure is still low.

We believe that the result of this study can help firms determine a strategic imperative for supporting innovative activities within their companies and among their employee-inventors. Furthermore, this study is expected to be an important starting point in figuring out the reason why the number of patent applications has recently increased rapidly in some nations, especially in Korea.

Despite the insights offered, this paper raises two more issues that require further investigation.

First, the values of patented inventions are not identical among firms, just as all inventions are not patented. Therefore, doubts are raised about whether patent count is a suitable way to analyze the R&D–patents relationship and subsequently as a measure of the efficiency of the innovation process. In this paper, we include firm size, industrial sector, and a firm's propensity to patent, which may affect patent production in the estimation model. The use of these variables may limit the problems arising from firms' different filing preferences. Unfortunately, however, a more general model that allows researchers to see how R&D affects the value of innovations has not been identified (Arora et al. 2008). So we assume that R&D only affects the number of innovations but not their value (Eaton & Kortum 1999; Arora et al. 2008). In this situation, it is hard to decide which firms use their R&D expenditures more effectively. For example, some firms may apply for fewer patents than other firms with similar R&D expenditures, but their patents may be more valuable in the market. Also, some people have suggested that employee-inventors are likely to apply for more patents than are needed for the sake of performance assessment. While accepting that this is a very complicated issue and patent count is the most commonly used measure of innovative output, we recognize the need to analyze the impact of innovation value on estimation results in future research.⁵

⁵ In this context, we have looked at whether noticeable differences can be found among firms with different levels of patent intensity and patent filing activities when they are compared in terms of registration rate and the number of claims. Maybe patent citations more highly correlated with highly valued inventions would provide better information than registration rate and the number of claims. However, patent documents of Korea do not include patent citation information. So we used a data set of registration rates and the number of claims. We found no evidence of difference in registration rate

Second, researchers need to consider the time lag that exists between R&D efforts and patent filings. Invention disclosures and patents come out based, in part, on research undertaken in previous years. Hence, many researchers estimated the coefficients between R&D and patents by setting time lags in their research. Others have found that R&D expenditures and patents have a contemporaneous relationship. For example, Han and Lee (2007) showed a contemporaneous relationship between R&D efforts and Korean patent applications with the stepwise regression method. Similarly, in this study, we assumed that R&D efforts and patent filings have a contemporaneous relationship. Using time lags, future research may clarify an empirical link between innovative output and R&D expenditure over previous years.

and the number of claims between firms that are more active in patent production and firms that are not.

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Tables

[Table 1] Description of explanatory variables	
Variable (acronym)	Description
Firm-specific characteristics	
Firm size (Firmsize)	log(number of employees)
Propensity to patent (PTP)	- Firm's self-judgment about the patent effectiveness for protection of innovation(1~5) - Value 5: very important, value 3: moderate, value 1: insignificant
IP lawsuit (Lawsuit)	Value 1: have experience in IP lawsuit; 0 otherwise
Efficiency parameters	
Preliminary patent search (PatSearch)	Value 3: conduct in-depth preliminary patent searches before starting R&D activities Value 2: conduct some patent searches before starting R&D activities Value 1: conduct patent searches after starting R&D activities or for patent application Value 0: does not conduct patent searches
IP manager (IPM)	The number of IP managers(full-time employees) in IPR department
Monetary incentive for employee-inventor (Money-pat)	The amount of a lump-sum bonus provided to employee-inventors when an application is filled in the patent office (US\$1000)
Non-monetary incentive for employee (Incentive)	Value 1: provide non-monetary incentive for employee's patent application (e.g., performance appraisals of employees) ; 0 otherwise
Monetary incentive for employee-inventor (Money-use)	Value 1: provide monetary incentives for employee-inventors as revenues resulting from the use of the patent by employer or third-party; 0 otherwise

[Table 2] Summary statistics of variables									
	ln (R&D ^a / employee)	Firmsize	PTP	Lawsui t	PatSear ch	IPM	Money -pat	Money × Incenti ve	Mone y -use
Mean	-2.431	3.838	4.187	0.146	1.678	0.522	0.081	0.031	0.087
S.D.	1.345	1.566	1.171	0.353	1.041	1.492	0.365	0.252	0.282
ln(R&D/ employee)	1								
Firmsize	-.373**	1							
PTP	.026	.041	1						
Lawsuit	.010	.153**	.077**	1					
PatSearch	.058*	.077**	.133**	.087**	1				
IPM	.034	.234**	.070*	.119**	.129**	1			
Money-pat	.019	.087**	-.006	.027	.039	.070*	1		
Money× Incentive	.047	-.008	.018	.056*	.036	.027	.672**	1	
Money-use	-.031	.239**	.052	.105**	.114**	.158**	.161**	.125**	1

^a R&D expenditure: US\$100000
 * Significant at the 0.05 level (2-tailed)
 ** Significant at the 0.01 level (2-tailed)

[Table 3] Patent applications and patent intensity

	Mean of patent applications ^a	S.D.	Patent intensity (Patent applications ^a /R&D ^b)
All firms (N=1,255)	9.52	104.92	0.414
R&D spending > \$500000 (N=539)	20.41	159.80	0.400
R&D spending ≤ \$500000 (N=716)	1.32	2.68	0.702
Machinery ^c (N=485)	7.67	41.40	0.469
Chemicals ^d (N=169)	5.74	17.41	0.249
Electronics (N=216)	28.19	242.73	0.723
Construction (N=101)	3.70	7.55	0.076
Business service (N=95)	3.48	6.85	0.189
Others (N=189)	2.45	4.73	0.239

^a Newly filed in 2006

^b R&D expenditure: US\$100,000 (in 2006)

^c including manufacture of medical, precision, and optical instruments

^d including manufacture of rubber and plastic products

[Table 4] Factors influencing the R&D-patents relationship: zero-inflated negative binomial regression

	Model 1 ^a	Model 2 ^a	Model 3 ^a	Model 4 ^a
ln R&D (US\$100,000)	.6108*** (.0574)			
ln(R&D/employee)		.2292*** (.0564)	.1231*** (.0444)	.1698* (.08829)
ln firm size		.7095*** (.0524)	.4620*** (.0352)	.5318*** (.0683)
Propensity to patent			.1570*** (.0381)	.2302*** (.0622)
IP lawsuit			.4351*** (.1426)	.4544*** (.1687)
preliminary patent search			.1307*** (.0458)	.1796*** (.0687)
IP manager			.1929*** (.0465)	.1917*** (.0567)
Money-pat			-.0815 (.1280)	-.0783 (.1459)
Incentive for employee (Money-pat × Incentive)			-.0082 (.1581)	-.0545 (.3861)
Money-use			.3346** (.1652)	.3679* (.2142)
Construction			.2411 (.2021)	.3751 (.3849)
Business service			.3268* (.1802)	.5920* (.3279)
Chemicals			-.0388 (.1614)	.1117 (.3187)
Machinery			.3188** (.1472)	.5527* (.3066)
Electronics			.2599 (.1669)	.5437* (.3101)
Wald χ^2 (p-value)	113.21 (.0000)	183.14 (.0000)	459.54 (.0000)	317.18 (.0000)
Number of observations	1255	1255	1255	539

^a Robust standard errors in parentheses
* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

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