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THE EFFECT OF R&D, TECHNOLOGY COMMERCIALIZATION CAPABILITIES AND INNOVATION PERFORMANCE

Seo Kyun Kim[1], Bong Gyou Lee[2], Beom Soo Park[3], Kyoung Seok Oh[4]

[1, 3, 4]ETRI, 138 Gajeongno, Yuseong-gu, Daejeon, 305-700, Korea
[2]Yonsei University, 262 Shinchon-dong, Seodaemun-gu, Seoul, 120-749, Korea
E-mails: [1]sk-kim@etri.re.kr; [2]bglee@yonsei.ac.kr;
[3]bspark@etri.re.kr (corresponding author); [4]verdi@etri.re.kr

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Abstract. This paper investigates the relationship between R&D capabilities (learning, R&D and external networking), technology commercialization (manufacturing and marketing), and innovation performance (product competitiveness) among SMEs in IT-related businesses. The study focuses on 254 Korean IT SMEs that were either recipients of government R&D grants or their indirect beneficiaries during the two-year period between 2005 and 2007. The major findings of this study are as follows: First, unlike what has been suggested by previous studies, R&D intensity was not the only factor influencing the innovation performance of firms; learning and external networking also had a significant influence on innovation. The research implication of this finding is that the measurement of firms' performance should not be solely based on the intensity of R&D expenditures, but a broader set of factors including learning and external networking capabilities. Second, the technology commercialization capabilities of firms played the role of a mediator in the relationship between R&D and innovation performance. Within the innovation cycle of input (R&D capabilities), process (technology commercialization capabilities) and output (innovation performance), we found that R&D seldom influenced performance in a direct fashion, but its influence was most often mediated by technology commercialization capabilities. The practical implication of this finding for companies is that in order to improve performance, they must avoid narrowly focusing on R&D, but must invest also in capabilities to commercialize technologies resulting from R&D. Third, when direct and indirect beneficiaries of public R&D funding are compared together, the explanatory power of the relationship between R&D capabilities, technology commercialization capabilities and innovation performance was stronger among the latter than the former.

Keywords: ETRI, technology commercialization capability, innovation performance, public R&D funding, R&D effect.

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JEL Classification: M130, M150, H510.

1. Introduction

1.1. Research background

A number of recent studies have investigated companies' internal characteristics which may influence their technological innovation performance (Lichtenthaler, Ernst 2007; David 2001; Tsai, Wang 2005; Lin *et al.* 2006). However, most of these studies on the innovation performance or innovative capabilities of IT SMEs have been too broad in their scope to meaningfully contribute to the understanding of the subject. They are oftentimes concerned either with the industry as a whole or an entire industry sector (service sector, manufacturing sector, etc.). Few of them deal with a specific subject related to IT SMEs, as does this study (investigation of technology innovation capabilities among IT SMEs that are direct and indirect beneficiaries of public R&D funding, including R&D capabilities and technology commercialization capabilities). On the other hand, there have been quite a few studies comparing economic performance between companies that receive government R&D subsidies and those that do not (Shin 2005; Kwon, Ko 2004; Lee 2004; David 2001; Lach 2002; Robson 2001). These studies, however, report conflicting results (mutually complementary effect vs substitutive effect). One of the reasons why past research on the relationship between R&D and technological innovation has failed to yield consistent results is that these studies were most often overly focused on one of the determinants of R&D innovation; namely, the independent effect of R&D, and largely overlooked the effect of moderating or mediating factors which could influence this same relationship (Kim 2003; O'Regan *et al.* 2006; Lach 2002). Also rare are studies investigating the effect of the many internal resources of firms (technology, manpower, organization, capital, etc.) which could potentially influence their innovation performance. Inquiries into the effect of R&D capabilities and technology commercialization capabilities required for commercializing the results of R&D on technology innovation performance have been especially rare (Yam *et al.* 2004; Lin *et al.* 2006). All in all, at a time when government R&D funding toward technology innovation among IT SMEs are continuously on the rise, the stock of research is surprisingly meager concerning the efficacy of such investment (David *et al*. 2000). There is, therefore, an urgent need to develop a clear understanding of how government funding affects the mechanism whereby R&D activities among IT SMEs lead to actual innovation performance. Currently, in Korea, IT SMEs are both directly and indirectly beneficiaries of government R&D funding. Some of them are direct recipients of government R&D grants, awarded toward independent technology development programs. Others benefit indirectly from public funding, as recipients of technologies developed in, and transferred from, government-sponsored or other publicly-funded research institutions, or as participants of joint R&D programs with these institutions.

1.2. Research objectives

This study borrows the seven capability dimensions proposed by Yam *et al.* (2004), namely, learning, R&D, resources allocation, manufacturing, marketing, organizing and strategy planning. Unlike the original model by Yam *et al.* (2004), in which the relationship between capabilities and innovation performance is examined by setting all of the seven dimensions as independent variables and innovation performance as the dependent variable, in this study, manufacturing and marketing are considered mediators in the correlation between R&D and innovation performance, as this relationship is analyzed as an input, process and output cycle.

The objectives of this study, in concrete, are to understand how the R&D and technology commercialization capabilities of IT SMEs that are direct or indirect beneficiaries of public funding, impact their technology innovation performance; what factors influence the technology innovation performance of these firms more than others; and whether there is a difference between the indirect and direct recipients of government R&D grants with regard to innovation performance and capabilities influencing this performance. Another aim of this study is to determine whether the technology commercialization capabilities of these firms serve as the mediator in the relationship between R&D and innovation performance. Finally, this paper presents research and policy implications drawn from the results of the above inquiry.

To sum up, the objectives of this study are three: First, cast light on the influence of two of the many potential factors affecting technology innovation in IT SMEs, namely, R&D capabilities (learning function, R&D function and external networking function) and technology commercialization capabilities (manufacturing function and marketing function), on their technological innovation performance. Second, determine whether technology commercialization capabilities play a mediating role between R&D capabilities and technological innovation performance, within the process of innovation, conceived in this study as a chain linking input (R&D capabilities), process (technology commercialization capabilities) and output (innovation performance). Third, investigate whether there is a difference between companies that are direct and indirect beneficiaries of public R&D funding in terms of how R&D capabilities and technology commercialization capabilities influence technological innovation performance.

2. Literature review

2.1. R&D capabilities and performance

R&D capability is generally understood as a dynamic capability related to the creation and use of knowledge, enabling a company to acquire and maintain its competitive advantage (Zahra, Gerald 2002). The importance of R&D capability has been confirmed by empirical studies attesting to the positive influence of direct efforts made by companies toward technological innovation (R&D spending per employee, ratio of R&D spending to sales, ratio of R&D employees to total employees, etc.) on their technological innovation performance (product innovation, number of patents, innovation indicators) (Romijin, Albaladejo 2002).

Meanwhile, for IT SMEs to enhance their technological capabilities, they must tap external knowledge resources to augment their internal capabilities with knowledge acquired from external sources. In the case of IT SMEs in catching-up countries, they need to absorb technology from more advanced countries. Obtaining external knowledge is more difficult, when the knowledge in question is tacit knowledge. Tacit knowledge is harder to capture than other forms of knowledge and requires a level of absorption capability on the part of learners (Zahra, Gerald 2002). Research has found that the capability of absorption, coupled with internal R&D investment, can effectively help accelerate technological cooperation and magnify the performance-enhancing effect of external know-how and technology, as well as strengthen external technological cooperation (Miotti, Sachwald 2003). Britton (1993) and Hagedoorn (1993) report that, in the case of IT SMEs, the ability to access external partners matter more than independent internal capabilities, and that inter-firm cooperation in the forms of joint R&D, patent sharing, collaborative development, technology transfer and joint venture have a positive influence on their innovation performance, as it complements internal technological capabilities and infrastructure.

Cassiman and Veugelers (2006) found that increase in internal R&D investment and technological cooperation with external organizations has a positive effect on the internal R&D capabilities of companies. Studies have also reported that technological development efforts are bound to be limited among IT SMEs, due to their lack of time and resources devoted to R&D and high-quality manpower, and because their technological knowledge is generally less than comprehensive, especially compared to large corporations, often confined to a few specific areas; for this reason, it is especially important for these firms to engage in partnerships or joint R&D programs to acquire external technology resources (Lee 2004; Kaufmann, Todtling 2002). Lerner (1999) in his study comparing the performance of 1,435 US firms receiving support from the SBIR with that of other firms benefiting from no such support, reports that companies that are recipients of government R&D grants grow at a faster rate, suggesting that public R&D funding plays an important role in enhancing companies' performance.

As for studies dealing with basic R&D capabilities of companies, they can be classified into three categories according to their focus: the focus in the research of the first category is the influence of R&D intensity at the level of simple R&D investment (input) on company performance. Studies of the second category second are principally concerned with the effect of strengthening R&D through inter-firm technological cooperation on the business performance and organizational performance of companies. The aim in the research of the third and last categories is to understand how R&D, understood as a learning-by-doing process, affects the performance of companies.

2.2. Technology commercialization capability and performance

Technology commercialization capability refers to the ability to absorb and re-adapt a new technology for use in production and marketing; in other words, the ability to integrate technology in concrete production and marketing activities (Jolly 1997). Nevens *et al.* (1990) define technology commercialization capability as the ability to rise above competitors and gain competitive advantage through cost reduction, quality improvement and the absorption of new technologies.

Chen (2009) in his study investigating factors influencing the performance of young ventures from a resource-based perspective, measures the effects of incubator programs, venture capital support and technology commercialization capabilities and reports that the role of technology commercialization is chiefly that of a mediator in the relationship between the organizational resources and innovative capabilities of companies, and their performance. As for Lin *et al.* (2006) and Lockett and Wright (2005), they analyzed technology commercialization capabilities of companies quantitatively, by calculating the ratio of marketing cost to sales, assuming that technology commercialization can be translated into the amount of company resources or efforts invested toward marketing technologies resulting from R&D in the form of a product or service. Meanwhile, Zahra and Nielsen (2002) in their resource-based view (RBV) study of companies, singled out among multiple dimensions involved in the commercialization of a technology, internal human resources and technology-based manufacturing sources as having a positive influence on the success of commercialization.

As for Schroeder *et al.* (2002) who investigated manufacturing companies' capabilities and resources from a resource-based view found that competitive advantage in manufacturing was influenced by the appropriateness of processes and equipment, and that external and internal learning played a highly significant role in a company's ability to gain or maintain a competitive advantage. Dutta *et al.* (1999) distinguished companies' capabilities into three types: marketing capability, R&D capability and operations capability, and analyzed how these three capabilities interacted with each other. The interaction between marketing and R&D capabilities, he found, had an important influence on a company's ability to develop new products and its overall performance. Meanwhile, marketing capabilities of companies, he reports, have the greatest influence of all on their innovative output. For companies in high-tech markets, long-term innovative capabilities and the ability to successfully commercialize their innovations (developing customer-oriented products) matter most particularly, he relates.

To sum up, findings by previous studies indicate that for technology-based IT SMEs, marketing capabilities, in other words, capabilities for successfully commercializing R&D results into competitive products, and manufacturing capabilities are nearly as important as R&D capabilities.

3. Research design

3.1. Survey

In this study investigating the relationship between R&D capabilities and technology commercialization capabilities of IT SMEs and their innovation performance, we narrowed our focus to IT SMEs that are direct recipients or public R&D funding and their indirect beneficiaries receiving technology support from government-sponsored R&D institutions. A month-long survey was conducted in August 2008, by email and fax, on 546 IT SMEs. 280 of them were direct recipients of government R&D grants at least at some point in the two-year period between 2005 and 2007, and 266 others, indirect beneficiaries, having benefited from R&D programs at government-sponsored institutions, either through simple technology transfer or as a participant of the programs, over the same period.

The goal being assessing the R&D capabilities, technology commercialization capabilities and innovation performance of IT SMEs, the survey was addressed to members of surveyed companies who by virtue of their official capacity possessed comprehensive knowledge of their organization's technology-related capabilities, such as the CEO, director of the R&D lab or the chief technology officer.

The response rate was 46%, with 262 out of a total sample population of 546 companies returning complete responses. After discarding eight of the 262 responses containing an excessive number of missing values, 254 responses were retained for analysis.

3.2. Research model

The research model draws on the seven capability dimension model proposed by Yam *et al.* (2004) – learning, R&D, Resources allocation, manufacturing, marketing, organizing, strategy

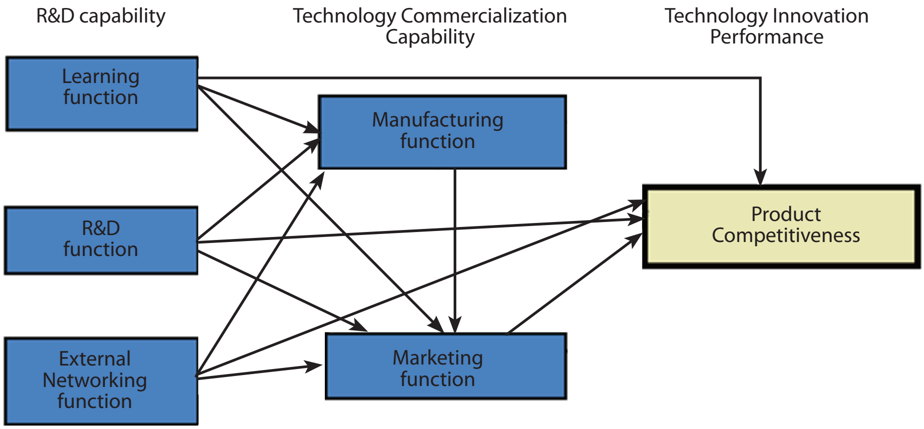

Fig. 1. Research model

planning – which was expanded with additional variables and appropriately modified to suit the purpose of this study.

In Yam *et al.*'s (2004) original model, the relationship between the seven capability dimensions and performance is examined by setting all seven dimensions as independent variables, and performance as the independent variable. We propose a new method as a research model (Fig. 1). In this study, consistent with the framework of innovation viewed as the cycle of input-process-output, manufacturing and marketing, the two technology commercialization capability variables, were treated as mediators of the influence of R&D on performance. Meanwhile, to take into consideration access to external resources, a potentially important influence factor for the innovative capabilities of IT SMEs, the model was further refined by adding the 'external networking function' as one of the R&D capability factors.

3.3. Definition of variables and survey measurement

The goal of this study is to analyze the relationship between R&D and technology commercialization capabilities of IT SMEs and their technological innovation performance. R&D capabilities, the independent variable, refers to all capabilities required for a company to develop innovative products, including those related to the acquisition, use and practical application of technology and knowledge.

We set up survey measurement as a presented Table 1. Three R&D capability-related measured variables were defined: learning function (function related to exploration, absorption and integration of external technology and knowledge / three items), R&D function (R&D workforce and the relative size of R&D investment / two items), and external networking function (function related to active external technology cooperation/ three items).

Technology commercialization capabilities, the independent variable as well as the mediator, comprehensively refer to all capabilities related to manufacturing and marketing, in other words, capabilities required in the process of modifying and re-adapting a technology for application in production, manufacturing and distribution of resulting products.

Table 1. Survey measurement

Construct	Variable	Measurement
R&D Capability	Learning Function (LF)	Monitoring about trends of R&D
		Absorption ability of External Knowledge
		Importance of Tacit Knowledge
	R&D function (RDF)	Relative size of R&D investment
		Relative size of R&D workforce
	External networking function(ENF)	New market entry through external Tech cooperation
		Synergy creation through external Tech cooperation
		Substantial help through external Tech cooperation
Technology Commercialization Capability	Manufacturing function (MFF)	Manufacturing process reflection of R&D
		Continuous improvement of manufacturing system
		Control of Product quality
		Chief manufacturing cost through new process
	Marketing function (MKF)	Knowledg holding for market segmentation
		Marketing ability of Sales man
		Sales ability of new product
Technology Innovation Performance	Product Competitiveness(PC)	Predominately at the cost side
		Competitveness of market
		Unique predominance of technology product

Two technology commercialization-related variables were defined: manufacturing function (function relevant to manufacturing products corresponding to market demand/ four items) and marketing function (function relevant to assessing customers' needs in a competitive environment and marketing products accordingly). Technological innovation performance, the dependent variable, is the indicator of innovation resulting from technological innovation capabilities or activities, and is measured in this study by product competitiveness (companies' self-assessment on their product performance / three items).

Except the two R&D function-related items, which were questions requiring the respondents to choose a percentage range, all other items were measured using a 7-point scale (1: not at all, 7: very much so).

4. Results of empirical analysis

4.1. Sample profile

As presented in Table 2, the sample surveyed totally 254 companies including direct company (government R&D fund recipient IT SMEs) and indirect company (ETRI Technology transfer & cooperation research IT SMEs). The sample comprised 119 companies that were direct recipients of government R&D grants during the period evaluated. The average number of years in operation among these companies was 6 years, average sales 830 million won, average capital 340 million won, and the average number of full-time employees 13.

Table 2. Sample profile

Division	Direct Company	Indirect Company
Company Number	119 (46%)	135 (54%)
Average Company age	6 years	9 years
H/W Company	77 (65%)	79 (58%)
S/W Company	42 (35%)	56 (42%)
2007 yrs sales average	830 million	2.5 billion
Average capital	340 million	530 million
Average employee	13	26

* Direct company: Government R&D Fund recipient IT SMEs
* Indirect company: ETRI Technoloy transfer & cooperation research IT SMEs

The number of companies that were indirect beneficiaries of government R&D funding making up the sample was 135. The average number of years in operation among these companies was 9 years, average sales 2.5 billion won, average capital 530 million won, and the average number of full-time employees 26. Companies that were indirect beneficiaries of government R&D funding were, therefore, somewhat larger in size than companies that were direct recipients of government grants, as well as superior to the latter in terms of sales performance.

4.2. Reliability and validity analysis

A regression analysis and a covariance structure analysis were performed on the data using SPSS 12.0 and AMOS 7.0. As can be seen in Table 3, all factors exceeded 1.0 in Eigen value, and the factor loadings of all measurement instruments were greater than the threshold of 0.7, confirming their convergence validity. Finally, to test the reliability of the data, Cronbach alpha values were calculated for each category of measurement items. The Cronbach alphas of the manufacturing function (MFF), external networking function (ENF), marketing function (MKF), learning function (LF) and the R&D function (RDF) were 0.896, 0.924, 0.828, 0.747, and 0.730, respectively, indicating a good level of reliability and validity.

Table 3. Factor analysis

Var	Measurement	Factors					α
		1	2	3	4	5	
MFF	Continuous improvement of manufacturing system	**0.865**	0.120	0.233	0.156	–0.046	0.896
	Manufacturing process reflection of R&D	**0.830**	0.196	0.089	0.228	0.088	
	Control of Product quality	**0.823**	0.141	0.255	0.084	0.006	
	Chief manufacturing cost	**0.784**	0.046	0.276	0.075	–0.021	
ENF	Synergy creation	**0.168**	0.926	0.094	0.178	0.022	0.924
	Substantial help	**0.151**	0.911	0.068	0.097	–0.015	
	New market entry	**0.095**	0.873	0.180	0.158	0.044	

End Table 3

Var	Measurement	Factors					α
		1	2	3	4	5	
MKF	Marketing ability	**0.218**	0.106	0.882	0.050	–0.056	0.828
	Knowledg holding	**0.248**	0.088	0.770	0.272	–0.026	
	Sales ability	**0.295**	0.156	0.743	0.090	0.024	
LF	Monitoring about trends of R&D	**0.163**	0.187	0.171	0.800	0.082	0.747
	Absorption ability	**0.176**	0.180	0.225	0.790	0.069	
	Tacit Knowledge	**0.082**	0.059	–0.002	0.731	0.016	
RDF	R&D Investment	**–0.030**	–0.006	–0.015	0.052	0.894	0.730
	R&D employee	**0.043**	0.043	–0.030	0.073	0.887	
Eigen value		**3.1**	2.6	2.3	2.1	1.6	
% of Variance		**20.4**	17.6	15.0	13.6	10.8	

4.3. Correlation analysis

A correlation analysis was performed to determine whether a relationship exists between each of the factors.

As shown in Table 4, the analysis found that the R&D function (RDF) had a significantly positive correlation only with product performance, and that all other functions, namely, learning function (LF), external networking function (ENF), manufacturing function (MFF) and marketing function (MKF), also had a positive correlation with innovation performance (product competitiveness: PC).

Table 4. Correlation analysis

Var	Mens	SD	LF	RDF	ENF	MFF	MKF	PC
LF	5.75	0.85	1					
RDF	3.39	0.77	0.133(*)	1				
ENF	4.91	1.33	0.384(**)	0.045	1			
MFF	5.04	1.07	0.401(**)	0.016	0.351(**)	1		
MKF	4.91	1.08	0.379(**)	–0.032	0.325(**)	0.553(**)	1	
PC	5.47	0.95	0.441(**)	0.259(**)	0.285(**)	0.507(**)	0.484(**)	1

4.4. Results of model test

The above-described research model was tested for structural goodness-of-fit (Table 5). The results obtained were RMR = 0.069, RMSEA = 0.069, TLI = 0.928, CFI = 0.943, NFI = 0.9. These results suggest that the model's goodness-of-it is very close to the optimal level.

Table 5. Goodness-of-fit result

Structural goodness-of-fit		Criterion	Result
Absolute Fit Measures	RMR	0.05–0.08	**0.069**
	RMSEA	0.1under	**0.069**
Incremental Fit Measures	TLI	0.9 over	**0.928**
	CFI	0.9 over	**0.943**
	NFI	0.9 over	**0.9**

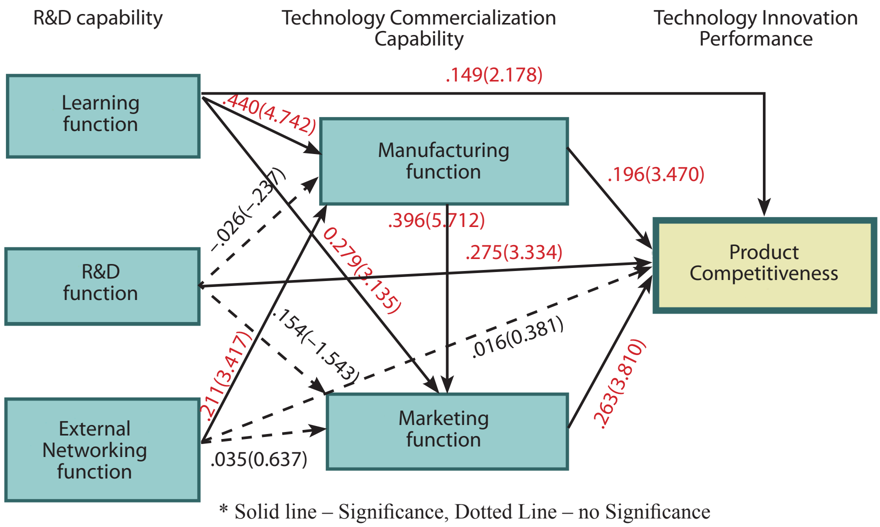

Fig. 2. Casual relation between constructs

The aim of this study is to explore the causal relationship that may exist between the R&D and technology commercialization capabilities of IT SMEs, and their innovation performance, and determine what factors influence innovation performance. The results of analysis are listed in Fig. 2 and Table 6.

First, the learning function (LF), one of the R&D capability-related factors, proved to have a significant positive influence on the manufacturing function (MF) and marketing function (MKF), the two technology commercialization capability-related factors, as well as on innovation performance (product competitiveness: PC). Second, the R&D function (RDF), another R&D capability-related factor, while it had no significant relationship with manufacturing function (MFF) or marketing function (MKF), had a significantly positive influence on innovation performance (product competitiveness: PC).

Third, the external networking function (ENF), the last of the three R&D capability-related factors, had a significant positive influence on the manufacturing function (MFF), but not on the marketing function (MKF) or innovation performance (product competitiveness: PC). Fourth, among the technology commercialization capability-related factors, whilst the manufacturing function (MFF) did not have a significant relationship with the marketing function (MKF), both the former and latter had a significant positive influence on innovation performance (product competitiveness: PC).

Meanwhile, the regression equation expressing innovation performance (PC) as a function of R&D and technology commercialization capabilities ($PC = \alpha + \beta_1$ R&D capabilities $+ \beta_2$ technology commercialization capabilities $+\varepsilon$) resulted in β values which suggested a significant relationship to innovation performance (PC) for both R&D capabilities (0.269) and technology commercialization capabilities (0.444). But, the β value of technology commercialization capabilities largely exceeded that of R&D capabilities, suggesting the existence of the mediating effect by the former.

Table 6. Path analysis result

Path	Path Coefficient	SD	t	p
LF → MFF	**0.440**	**0.093**	**4.742**	**0.000**
LF → MKF	**0.279**	**0.089**	**3.135**	**0.002**
LF → PC	**0.149**	**0.068**	**2.178**	**0.029**
RDF → MFF	–0.026	0.109	–0.237	0.812
RDF → MKF	–0.154	0.100	–1.543	0.123
RDF → PC	**0.275**	**0.082**	**3.334**	**0.000**
ENF → MFF	**0.211**	**0.062**	**3.417**	**0.000**
ENF → MKF	0.035	0.056	0.637	0.524
ENF → PC	0.016	0.041	0.381	0.703
MFF → MKF	**0.396**	**0.069**	**5.712**	**0.000**
MFF → PC	**0.196**	**0.056**	**3.470**	**0.000**
MKF → PC	**0.263**	**0.069**	**3.810**	**0.000**

Furthermore, the results of the regression equation consisting of low-level items of R&D and technology commercialization capabilities ($PC = \alpha + \beta_1\ LF + \beta_2\ RDF + \beta_3\ ENF + \beta_4\ MMF + \beta_5\ MKF + \varepsilon$) indicated that all items except ENF were significant. However, the MMF (0.272) and MKF (0.261) had a greater influence on innovation performance than LF (0.191) and RDF (0.237); hence the mediators.

4.5. Comparison of regression analysis results between direct and indirect recipients of government R&D funds

Table 7 lists the results of the regression analysis, showing differences between IT SMEs that were direct recipients of public R&D funding (internally carrying out pubic-funded R&D projects) during the period studied, and those that are their indirect beneficiaries (technology transfer from ETRI or participation in joint research projects) in terms of how R&D and technology commercialization capabilities influence their innovation performance.

Table 7. Direct/indirect regression result

Dependent	Independent	Direct SMEs (N = 119)		Indirect SMEs (N = 135)	
PC	**LF**	**0.200***	F = 4.333** R = 0.321 R_2 = 0.103 Ajut R_2 = 0.079	**0.415****	F = 20.700** R = 0.570 R_2 = 0.325 Ajut R_2 = 0.309
	RDF	0.159		**0.191****	
	ENF	0.129		0.163	
PC	**MFF**	**0.256****	F = 15.433 R = 0.458 R_2 = 0.210 Ajut R_2 = 0.197	**0.384****	F = 39.133** R = 0.610 R_2 = 0.372 Ajut R_2 = 0.363
	MKF	**0.290****		**0.285****	
MFF	**LF**	0.138	F = 4.257** R = 0.319 R_2 = 0.102 Ajut R_2 = 0.078	**0.390****	F = 16.591* R = 0.528 R_2 = .0278 Ajut R_2 = 0.262
	RDF	–0.090		**–0.024**	
	ENF	**0.246****		**0.216***	
MKF	**LF**	**0.221***	F = 3.975** R = 0.309 R_2 = 0.095 Ajut R_2 = 0.071	**0.321****	F = 16.357** R = 0.525 R_2 = 0.276 Ajut R_2 = 0.259
	RDF	0–.018		**–0.166***	
	ENF	0.167		**0.279****	

* $P < 0.05$, ** $P < 0.01$

The results indicate that among companies that were direct recipients of government grants, only one of the R&D capability-related factors, namely, the learning function (LF), yields a moderate positive influence on innovation, with other factors such as the R&D function (RDF) and external networking function (ENF) having no significant influence. As for technology commercialization capabilities, both the manufacturing function (MFF) and marketing function (MKF) had a significant positive relationship to innovation performance (product competitiveness: PC). Concerning the relationship between R&D capabilities and technology commercialization capabilities, only the external networking function and learning function (LF) had a significant positive influence on the manufacturing function (MFF) and marketing function (MKF), respectively. Among firms that were indirect beneficiaries of public R&D funding, two R&D capability-related factors, namely, the learning function (LF) and R&D function, showed a significant positive correlation with innovation performance (product competitiveness: PC). In terms of the relationship between technology commercialization capabilities and innovation performance, both the manufacturing function and marketing function (MKF) exerted a significant positive influence on innovation performance. Concerning the relationship between R&D capabilities and technology commercialization capabilities, we found that the learning function (LF) and external networking function (ENF) produced a significant positive influence on technology commercialization capabilities, with the R&D function having no significant correlation.

Notably, both the learning function (LF) and external networking function (ENF) had a significant positive correlation with the marketing function, whereas the R&D function showed a significant negative correlation with the marketing function. Meanwhile, the regression model was tested for possible multicollinearity, and the results indicated no presence of multicollinearity.

We were further able to compare the direct recipients of government R&D grants and their indirect beneficiaries, in terms of the explanatory power of variables, using coefficients of determination, and determine what factors had more explanatory power than others.

As can be seen in (Fig. 3), the explanatory power of the relationship between R&D capabilities and innovation performance stood at 10.3% for companies that are direct recipients

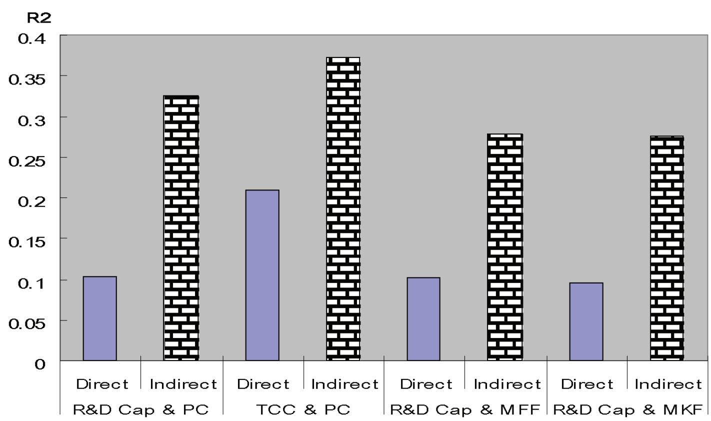

Fig. 3. Explanatory power result

of government funds, and 32.5% for companies that are their indirect beneficiaries. With regard to the relationship between technology commercialization capabilities and innovation performance (product competitiveness: PC), its explanatory power was also substantially higher with companies that are indirect beneficiaries of government R&D funding (37.2%) than with companies that are the direct recipients of it (21%). The disparity in explanatory power remained as wide between the two groups, also concerning the relationship between R&D capabilities and the manufacturing function (MFF): 10.2% for companies that are direct recipients of government funds and 27.8% for those that are their indirect beneficiaries. The same pattern persisted with the relationship between R&D capabilities and the marketing function (MKF), whose explanatory power was dramatically higher among the indirect beneficiaries of public funding (27.6%) than the direct recipients of government funds (9.5%). To sum up, the explanatory power of the relationship between R&D capabilities, technology commercialization capabilities and innovation performance, measured by coefficients of determination, was far greater with IT SMEs that are indirect beneficiaries of government R&D funding than those that were direct recipients. The principal implication of these results is that indirect investment through government-sponsored research institutions is measurably more effective in enhancing the technological innovation performance of IT SMEs, than direct investment in the form of funding companies' internal R&D projects.

5. Conclusion and implications

The main findings of this study are as follows: First, in the relationship between R&D capabilities (LF, RDF, ENF), technology commercialization capabilities (MFF, MKF) and technological innovation performance (PC), the learning function (LF) had a significant influence on both technology commercialization capabilities and innovation performance, playing a crucial role in the ability of IT SMEs to effectively commercialize R&D results as well as in their overall innovation performance. On the other hand, the R&D function (RDF) only influenced innovation performance, and technology commercialization capabilities proved to have no significant correlation with innovation performance. As for the external networking function (ENF), this factor had a measurable influence only on the manufacturing function (MFF), and not on innovation performance or the marketing function.

The results, therefore, suggest that technological cooperation with external organizations does not influence the innovation performance or marketing performance of companies, and this may be explained by the fact that external cooperation activities are generally centered on R&D exchange and exchange of product manufacturing technologies. Meanwhile, the manufacturing function (MFF) and marketing function (MKF), the two technology commercialization capability-related factors appear to have a highly significant influence on the innovation performance of IT SMEs. The manufacturing function (MFF) and marketing function (MKF) also showed a direct correlation with each other.

These results point to the importance of considering a comprehensive set of R&D capabilities, when measuring the influence of R&D on the innovation performance of companies, including learning and external networking functions, and not just focusing on R&D intensity, as is the case with much of the existing literature.

Second, technology commercialization capabilities played the role of a mediator between R&D capabilities and innovation performance (product competitiveness: PC). As shown in Table 5 above, the goodness-of-fit of the research model used in this study is very close to the optimal level, confirming that the technology commercialization capability-related variables are mediators in the relationship studied. The β value in the regression analysis was also significantly higher for technology commercialization capabilities (0.444) than for R&D capabilities (.269). The same was true with the β values of low-level technology commercialization capability variables, attesting to the fact that technology commercialization capabilities exert a far greater influence on the innovation performance of IT SMEs than do R&D capabilities.

The practical implication of the mediating role played by technology commercialization capabilities between R&D capabilities and innovation performance is that companies, in their technology development efforts should not narrowly focus on R&D, but consider also commercialization-related factors, so that resulting technologies can effectively lead to concrete enhancement of performance.

Third, the correlations between R&D capabilities, technology commercialization capabilities and innovation performance differed substantially between companies that are direct recipients of government funds, and those companies that are their indirect beneficiaries. R^2 , the measure of the explanatory power of independent variables was dramatically higher among indirect beneficiaries of public R&D funding than direct recipients of government grants, concerning all three variables including R&D capabilities, technology commercialization capabilities and innovation performance. The policy implication of this finding would be that government can more effectively bring forth the enhancement of national technological competitiveness through indirect investment in IT SMEs, in other words, by channeling public R&D funding toward government-sponsored research institutions, than through direct investment.

Currently, in South Korea, government support for R&D activities in IT SMEs is provided in two forms: direct disbursement of funds to companies on their internal development projects, and indirect support, giving them access to technologies developed by government research institutions. Based on the findings of this study, transferring technologies developed by research organizations possessing high-quality manpower and equipment to IT SMEs, in a state ready for commercialization and with greater value-added, is a better way of assisting them in gaining technological competitiveness.

References

Britton, J. N. H. 1993. A regional industrial perspective on canada under free trade, *International Journal of Urban and Regional Research* 17: 559–577. doi:10.1111/j.1468-2427.1993.tb00241.x

Cassiman, B.; Veugelers, R. 2006. In search of complementarity in innovation strategy; internal R&D and external knowledge acquisition, *Management Science* 52(1): 68–82. doi:10.1287/mnsc.1050.0470

Chen, C. J. 2009. Technology commercialization, incubator and venture capital and new venture performance, *Journal of Business Venturing* 62(1): 93–103. doi:10.1016/j. jbusres.2008.01.003

David, D. L. 2001. The role of R&D intensity, echnical development and absorptive capacity in creating entrepreneurial wealth in high technology start-ups, *Journal of Engineering and Technology Management* 18: 29–47. doi:10.1016/S0923-4748(00)00032-1

David, P.; Hall, B.; Toole, A. 2000. Is public R&D a Complement or Substitute for Private R&D: A Review of the Econometric Evidence, *Research Policy* 29(4–5): 497–529. doi:10.1016/S0048-7333(99)00087-6

Dutta, S.; Narasimhan, O.; Rajiv, S. 1999. Success in High-Technology Markets; is marketing capability critical?, *Marketing Science* 18(4): 547–568. doi:10.1287/mksc.18.4.547

Hagedoorn, J. 1993. Understanding the rational of strategic technology Partering; Interorganizational modes of cooperation and Sector Differences, *Strategic Management of Journal* 14(5): 371–385. doi:10.1002/smj.4250140505

Jolly, V. K. 1997. *Commercializing new technologies.* Cambridge, Harvard Business School Press.

Kaufmann, A.; Todtling, F. 2002. How effective is Innovation Support for SMEs ?; an analysis of the region of Upper austria, *Technovation* (22): 147–159. doi:10.1016/S0166-4972(00)00081-X

Kim, J. B. 2003. A performance and subject of the policy on SMEs, in *KAPS academic seminar*, 126–189.

Kwon, N. H.; Ko, S. W. 2004. The effects of governement R&D Direct subsidies on corporate R&D Investments, *Kukje Kyungje Yongu* 10(2): 157–181.

Lach, S. 2002. Do R&D Subsidies Stimulate or displace private R&D Evidence from Israel, *Journal of Industrial Economics* 50(4): 369–390. doi:10.1111/1467-6451.00182

Lee, B. K. 2004. Government and private business research and development; are they complements or substitutes, *Korea Economic Research Institute* (04–07): 64–67.

Lerner, J. 1999. The government as venture capitalist: the long-run impact of the SBIR Program, *Journal of Business* 72(3 Jul): 285–318.

Lichtenthaler, U.; Ernst, H. 2007. External technology commercialization in large firm; result if a quantitative benchmarking study, *R and D Management* 37(5): 383–397. doi:10.1111/j.1467-9310.2007.00487.x

Lin, B. W.; Lee, Y. K.; Hung, S. H. 2006. R&D intensity and commercialization orientation effect on financial performance, *Journal of Business Research* 59: 679–685. doi:10.1016/j.jbusres.2006.01.002

Lockett, A.; Wright, M. 2005. Resources, capability, risk capital and the creation of university spin-out companies, *Reserch Policy* 34(7): 1043–1057. doi:10.1016/j.respol.2005.05.006

Miotti, L.; Sachwald, F. 2003. Co-operative R&D; why and with whom; an integrated framework of analysis, *Research Policy* (32): 1481–1499. doi:10.1016/S0048-7333(02)00159-2

Nevens, T. M.; Summe, G. L.; Uttal, B. 1990. Commercializing technology; what the best companies do?, *Harvard Business Review* (May/Jun): 154–163.

O'Regan, N.; Ghobadian, A.; Sims, M. 2006. Fast Tracking Innovation in Manufacturing SMEs, *Technovation* 26(2): 251–261. doi:10.1016/j.technovation.2005.01.003

Robson, M. T. 2001. Federal funding and the level of private expenditure on basic research, *Southern Economic Journal* 60: 63–71. doi:10.2307/1059931

Romijin, H.; Albaladejo, M. 2002. Determinants of innovation capability in small electronics and software firms in southeast england, *Research Policy* 31: 1053–1067. doi:10.1016/S0048-7333(01)00176-7

Schroeder, R. G.; Bates, K. A.; Junttila, M. A. 2002. A Resource-Based view of manufacturing strategy and the relationship to manufacturing performance, *Strategic Management Journal* 23(2): 105–117. doi:10.1002/smj.213

Shin, T. Y. 2005. The analysis of empirical about the intercomplementariry of the government R&D and private R&D, *Science and Technology Policy Issues* (151): 54–73.

Tsai, K. H.; Wang, J. C. 2005. Does R&D Performance decline with firm size? A re-examination in terms of elasticity, *Research Policy* (34): 966–976. doi:10.1016/j.respol.2005.05.017

Yam, R. C. M.; Guan, J. C.; Pun, K. F.; Tang, E. P. Y. 2004. An audit of technological innovation capabilities in chinese firms; some empirical findings in Beijing, China, *Research Policy* (33): 1123–1140.

Zahra, S. A.; Gerald, G. 2002. Absorptive capacity; a review, reconceptualization and extension, *Academy of Management Review* 27(2): 185–203.

Zahra, S. A.; Nielsen, A. P. 2002. Sources of capabilities, intergration and technology commercialization, *Strategic Management Journal* (23): 377–398. doi:10.1002/smj.229

MOKSLINIŲ TYRIMŲ IR EKSPERIMENTINĖS PLĖTROS BEI TECHNOLOGIJŲ KOMERCIALIZAVIMO GALIMYBĖS ĮTAKA INOVACIJŲ EFEKTYVUMUI

S. K. Kim, B. G. Lee, B. S. Park, K. S. Oh

Santrauka. Straipsnyje tiriamas ryšys tarp mokslinių tyrimų ir eksperimentinės plėtros (MT ir EP), technologijų komercializavimo (gamybos ir rinkodaros) bei inovacijų efektyvumo (produkto konkurencingumo) smulkiose ir vidutinėse informacinių technologijų (IT) įmonėse. Buvo tiriamos 254 Korėjos smulkios ir vidutinės IT įmonės, kurios buvo valstybės paramos gavėjos arba gavo netiesioginę paramą 2005–2007 m. Pagrindinės tyrimo išvados yra šios: mokslinių tyrimų ir eksperimentinės plėtros mastas nėra vienintelis veiksnys, darantis įtaką inovacijų efektyvumui įmonėse; mokymas ir išorinis komunikavimas taip pat daro didelę įtaką inovacijoms. Taigi įmonių veiklos vertinimas neturėtų būti grindžiamas tik mokslinių tyrimų ir eksperimentinės plėtros intensyvumu, bet ir kitais veiksniais, kaip mokymo ir išorinio komunikavimo galimybės. Įmonės turėtų investuoti į galimybes komercializuoti technologijas, sukurtas mokslinių tyrimų ir eksperimentinės plėtros metu.

Reikšminiai žodžiai: technologijų komercializavimas, inovacijų efektyvumas, moksliniai tyrimai ir eksperimentinė veikla.

Seo Kyun KIM is a Ph.D., Principal Researcher in ETRI. His research areas are management of technology and Commercialization in IT and IT Fusion industry. He got a Ph.D in management of technology by the Yonsei University in Korea. Now He works at the ETRI(Electronics and Telecommunications Research Institute; world best IT institutes) in Korea as a SME Cooperation Team member.

Bong Gyou LEE is the Associate Dean and a Professor in the Graduate School of Information at Yonsei University. He received his BA Degree from Yonsei in 1988 and his MS Degree in 1992 and PhD in 1994 from Cornell University. He was a commissioner of the Korea Communications Commission in 2007 and 2008.

Beom Soo PARK is a Ph.D., SME Team Leader in ETRI. His research areas are International Management and Commercialization of IT SMEs. He got a Ph.D in international management by the Korea University in Korea. Now He works at the ETRI in Korea as a SME Cooperation Team Leader.

Kyoung Seok OH is a Ph.D. Student at GSI, Yonsei University. He received his M.S in management from Chungnam National University, Korea. His research interests include Technology Strategy and Regulation Policy.