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The effect of external search on innovation performance and speed

외부지식의 탐색이 혁신성과와 혁신속도에 미치는 영향

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외부지식의 탐색이 혁신성과와 혁신속도에 미치는 영향

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Abstract

Since Chesbrough (2003) brought up the idea of "open innovation", many firms have used open search strategy. This paper tries to examine the effect of external search on innovation performance and speed. Based on Korean Innovation Survey (KIS) of 1353 manufacturing firms in Korea, I find that searching deeply

from external sources is positively related to radical innovation performance. In contrast, searching broadly from external sources is positively related to incremental innovation performance. In addition, search breadth is negatively related to innovation speed. These findings implicate that aligning open search strategy with a firm's goal is important. In other words, searching deeply or broadly may depend on whether the firm intends to introduce "new to world" products or "new to firm" products. Also, firms should consider innovation speed in applying search strategy.

keywords : open innovation, external search, innovation performance, innovation speed

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INTRODUCTION

Firms often confront the risks of knowledge spill-over to rival firms. Thus, firms traditionally tried to protect valuable knowledge (Libeskind, 1997). However, Chesbrough (2003) changed this conventional wisdom of protection as he brought up the concept of "open innovation". Since then, open innovation has received much attention from both scholars and managers.

Chesbrough (2003) argues that firms are "too focused internally" and thus firms are likely to miss opportunities in the market. New opportunities can arise from both deploying outside and in-house resources. By using external knowledge, firms can lower the risk gained from the mobility of workers. Leveraging internal and external experience is important in enhancing R&D project performance (Hoang and Rothaermel, 2010) because internal investments and external resources can be complementary (Cassiman and Veugelers, 2006).

According to Bahemia and Squire (2010), studies on open innovation can be divided into several perspectives. Some scholars focus on R&D cooperation (Becker and Dietz, 2004; Miotti and Sachwald, 2003; Nieto and Santamaria, 2007; Belderbos et al., 2004; Faems et al., 2005; Tether, 2002) while others focus on alliances (Rothaermel and Deeds, 2006). Recently, scholars are conducting

research about external knowledge sourcing in open innovation (Roper et al., 2008; Tether and Tajar, 2008; Amara and Landry, 2005; Laursen and Salter, 2004).

External search of knowledge is considered important to the firm's innovation (Cohen and Levinthal, 1990; Rosenkopf and Nerkar, 2001; West and Bogers, 2014). For example, supplier, customer, rival, university, consultant, community can be sources of external knowledge (Van de Vrande et al., 2009; Su et al., 2009; Kang and Kang, 2010; Dahlander and Magnusson, 2008). However, prior research on external search and innovation performance neglected the importance of the novelty of innovation and innovation speed. Thus, my study intends to link breadth and depth of external search to the novelty of innovation and innovation speed.

The research is based on a statistical analysis of Korean Innovation Survey (KIS) conducted by Science and Technology Policy Institute (STEPI), an organization supported by government funding. The survey consists of 3925 manufacturing firms in Korea and explores the innovation performance of firms for the period of 2007-2009. I find that the depth of external search is positively related to radical innovation. On the other hand, the breadth of external search is positively related to incremental innovation. Also, breadth of external search is negatively related to the innovation

speed.

THEORY AND HYPOTHESES

Open innovation and external search

The concept of "open innovation" was initiated by Chesbrough (2003). He emphasizes the use of both external knowledge and internal knowledge. He asserts that "Firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology". Chesbrough et al. (2006) point out that "open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets".

Open innovation research can be categorized in to two streams (Chesbrough and Crowther, 2006; Dahlander and Gann, 2010): inbound open innovation (Inauen and Schenker-Wicki, 2011; Parida et al., 2012) and outbound innovation (Lichtenthaler, 2009). Inbound open innovation refers to the acquisition of technology from external sources and the application of external knowledge into innovation activities. In contrast, outbound open innovation refers to outward transfer of technological knowledge. Sometimes firms combine inbound and outbound open innovation to innovate

(Gassmann and Enkel, 2004; Gassmann et al., 2010; Enkel et al., 2009; Lichtenthaler, 2011).

Considering open innovation as the processes of external search belongs to inbound open innovation literatures. A firm's external knowledge search process includes "organization's problem-solving activities that involve the creation and recombination of technological ideas" (Katila and Ahuja, 2002). The definitions of external search breadth and depth in open innovation literature were first suggested by Laursen and Salter (2006). Laursen and Salter (2006) borrow the concepts of external search breadth and depth from Katila and Ahuja (2002), and link the concepts of search breadth and depth to open innovation. However, the definitions of search breadth and depth of Laursen and Salter (2006) differ from those of Katila and Ahuja (2002).

Katila and Ahuja (2002) refer search scope to how widely the firm explores new knowledge and measured it by "share of citations found in a focal year's citations that could not be found in the previous fivers' list of patents and citations by the firm. Also, they see search depth as how the firm reuses its existing knowledge, and it is measured by "the number of times a firm repeatedly used the citations in the patents it applied for".

On the other hand, Laursen and Salter (2006) define

external search depth as "the extent to which firms draw deeply from the different external sources or search channels". In addition, they measure external search breadth as "the number of external sources or search channels that firms rely upon in their innovative activities".

In brief, Katila and Ahuja (2002) extend the view of March (1991) by adopting the concepts of exploration and exploitation. Katila and Ahuja (2002) try to measure search breadth and depth as the patent citations while Laursen and Salter (2006) focus on measuring the sources of knowledge. The diversity of information sources can be used as an indicator of openness (Fey and Birkinshaw, 2005). In this research, I adopt the concepts of search breadth and depth from Laursen and Salter (2006).

Proctor and Gamble (P&G) is one of the companies which brought open innovation as a successful driver of the product development. Traditionally, P&G was protective about its technologies and patents so P&G was reluctant to license to outsiders. However, in 2000, P&G started to collaborative with outsiders using a Connect and Develop strategy (Sakkab, 2002). Connect and Development is a project using internet connections to upload and share internal and external data. In 2002, over 9 million documents were uploaded online. P&G's strategy was to

extensively use external source of information. P&G aimed to use external source of information up to 50% of product development. In addition to using Connect and Develop strategy, P&G used networks of technological entrepreneurs (Huston and Sakkab, 2006). P&G also created a Technology Acquisition Group to license-in technologies from external sources and license-out its own technology (Dodgson et al., 2006). Larry Huston, a vice president of Knowledge and Innovation P&G Worldwide R&D, mentioned that due to efforts toward open innovation, P&G' s innovation success rate more than doubled and R&D productivity increased by nearly 60% (Huston and Sakkab, 2006).

Radical innovation, incremental innovation, and external search

Innovations can be divided in to two categories-radical innovation and incremental innovation- based on the degree of product novelty (Banu Goktan and Miles, 2011). Differentiation between radical innovation and incremental innovation is the newness of product (Johannessen et al., 2001).

As Subramaniam and Youndt (2005) conceptualize, incremental innovative capability is "the capability to generate innovations that refine and reinforce existing products and services

and radical innovative capability is "the capability to generate innovations that significantly transform existing products and services". Gatignon et al. (2004) recognize incremental innovation as "improving and exploiting an existing technological trajectory", whereas radical innovation as "disrupting an existing technological trajectory".

Recent studies show that knowledge base of a firm shapes radical innovation (Hill and Rothaermel, 2003; Miller et al., 2007; Zhou, 2010). However, scholars show conflicting opinions about the impact of knowledge breadth and depth on radical innovation. Taylor and Greve (2006) argue that firms with diverse knowledge base are more likely to create new ideas and bring those ideas into novel products. In contrast, Zahra and George (2002) suggest that in-depth knowledge in a specific industrial field plays a crucial role in realizing the cutting-edge ideas. This paper is one of the efforts to find out how breadth and depth of external search are related to radical innovation and incremental innovation.

Radical innovation is the novel and unique technological advancement in product development which alters the consumption patterns of customers in a market (Gatignon et al., 2002). Radical innovations possess new knowledge and clear departures from existing practices. Managers are required to combine aspects of

technological and customer knowledge in completely new ways in order to achieve radical product innovation (Henderson and Clark, 1990). Frequent and strong contacts with a particular knowledge source can boost the in-depth knowledge so firms can induce fine-grained innovations (Leana and Van Buren, 1999; Dyer and Nobeoka, 2000). By having an in-depth look into particular sources of external knowledge, employees can overcome Not Invented Here (NIH) syndrome, an employee's hostile attitude toward external learning (Katz and Allen, 1982). It is suggested that employees may be threatened or act resistant toward the new idea generated by external sources because the idea is not initiated in-house (Kessler et al., 2000). Negative attitude toward external knowledge acquisition decreases inbound open innovation (de Araújo Burcharth et al., 2014). However, deep research into new external knowledge would help employees overcome NIH because employees can put much time in getting familiar with new external ideas. In addition, with limited resources, being focused by learning deeply from some external sources would be effective in realizing radical innovation. In-depth examination at new and fresh ideas can promote radical innovation. Accordingly, the hypothesis can be stated as the below.

Hypothesis1. External search depth is positively related to radical innovation performance.

Some scholars assert that the breadth of knowledge sources is positively associated with innovation success at the firm level (Leiponen and Helfat, 2010; Love et al., 2014). Ebersberger and Herstad (2011) found that the diversity of innovation information sources is positively related to the likelihood of new product introduction. The great positive impact on new product innovation comes from diverse collaborative networks, meaning that having diverse partners is important (Nieto and Santamaria, 2007). Diverse connections with a wide range of knowledge sources are important drivers of creative works (Hargadon and Bechky, 2006). Wide exposure to information is needed to provide better technological solutions to customers (Hargadon and Sutton, 1997). However, although breadth of external search can increase new product innovation, handling various sources can be costly and complex. If there are too many sources of knowledge, employees cannot stay focused. According to the resource-based view, resources are limited. Thus, it would be hard to expect radical innovation when search breadth is enlarged. When search breadth increase, resource allocation becomes the problem. Thus, external search breadth may be related to incremental innovation rather than radical innovation. These arguments lead to the following hypothesis.

Hypothesis2. External search breadth is positively related to

incremental innovation performance.

Search breadth, depth and innovation speed

In today's global economy, competitions among firms have become fierce so product life cycles have shortened. Firms can take advantages of large market share and profits by reducing product life cycle (Karlsson and Ahlstrom, 1999). Overall, the importance of speeding up an organization's operations to build competitive advantage has increased (Brown and Karagozoglu, 1993; Page, 1993; Smith and Reinertsen, 1992; Vesey; 1991).

Firms continuously try to improve the product development cycle in order to take first mover advantages (Griffin, 1997; Jones, 2003). The faster development of a new product leads to the greater likelihood of achieving first mover advantages or pioneering advantages (Lieberman and Montgomery, 1988; Emmanuelides, 1991). First mover advantage is good for firms because pioneering firm can set standard of the market and build up strong brand image.

Innovation speed is defined as the time elapsed between initial development and ultimate commercialization (Mansfield, 1988; Murmann, 1994; Vesey, 1991). Initial development includes the conception and development of new product. Ultimate commercialization means the introduction of a new product to the

marketplace.

Innovation speed is particularity important for firms competing in an environment where technology changes rapidly (Parry et al., 2009). Rapid technological change leads to rapid obsolescence of products (Bernstein and Singh, 2008). Therefore, the ability to launch a product ahead of others is crucial to be competitive in markets (Allocca and Kessler, 2006).

Despite the importance of innovation speed, research about innovation speed is limited. Innovation speed is one of the least studied factors in the literatures on new product development (Montoya-Weiss and Calantone, 1994; Kessler and Chakrabarti, 1996). In specific, most existing studies are based on project level (Kessler and Bierly, 2002; Seidel, 2007). In my research, I try to bring the scope of innovation speed down to firm level and analyze how innovation speed is related to types of external search.

Product development involves complex and uncertain processes. In specific, implementation of open innovation involves three stages: unfreezing, moving and institutionalizing (Chiaroni et al., 2011). Especially when firms search broadly, the attention of employees are likely to be distracted. Many firms fail in implementing promising new ideas because they lack sufficient expertise to solve complex problems (Katz and Du Preez, 2008).

Also, allocating resources becomes an important matter when resources are limited. Garriga et al. (2013) argue that constraints on the application of resources affect the breadth and depth of knowledge sourcing in open innovation. If search breadth is too broad, resources may not be allocated fully into learning particular knowledge which is needed to produce new products. Thus, it would be hard to reduce product development time. In sum, the hypothesis is stated as the following.

Hypothesis3. External search breadth is negatively related to innovation speed.

On the other hand, building up in-depth knowledge from external sources can reduce innovation speed because employees can be focused and put hard efforts into learning particular sources of knowledge. In addition, firms would have less difficulty in handling the resources. Implementation of ideas into new product development would be easier when resources are put enough. Learning in-depth knowledge and allocation of resources into particular sources would speed up the innovation. Based on the above, I propose the following hypothesis.

Hypothesis4. External search depth is positively related to innovation speed.

DATA AND METHODS

Sample

The data for the analysis are drawn from Korean Innovation Survey (KIS) conducted by Science and Technology Policy Institute (STEPI), a research institute supported by government funding. Korean Innovation Survey (KIS) data is similar to Eurostat Community Innovation Survey (CIS) of innovation which is commonly used in open innovation research (Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010; Klingebiel and Rammer, 2014). Both KIS and CIS capture the sales of new product. Main advantage of CIS is that CIS data offer "a direct measure of success in commercializing innovations for a broad range of industries" that more traditional measures such as patents may not capture (Leiponen and Helfat, 2003). KIS questionnaire explores the innovation performance of 3925 manufacturing firms in Korean for the period of 2007-2009. However, only a full set of data of 1353 firms are used in this study after 762 miscoded data and 1810 data with no information about important control variables are excluded.

Dependent variables

Performance of product innovation is conceptualized as the

extent to which a firm successful commercializes the new product. Consistent with prior studies (Garcia and Calantone, 2002; Laursen and Salter, 2006; West et al., 2014) typologies for novel innovation practice include "new to world", "new to firm", and "product significantly improved". Radical innovation is measured as sales of product "new to world" over total sales. Incremental innovation is divided into two categories: "new to firm" and "product significantly improved". One is measured as sales of product "new to firm" over total sales. The other is measured as sales of product "significantly improved" over total sales. Together, three variables add up to 100% for each firm.

Independent variables

I follow Laursen and Salter (2006) in measuring search breadth and search depth. As stated in the paper, search breadth is how broadly a firm uses external source of information. Thus, search breadth is measured by the combination of the 11 sources of external knowledge or information. 11 sources of external knowledge include subsidiary, supplier, customer, competitor, partner, new hires, consultant, university, government, conference, and publication. First, 11 sources are coded 0 being no use 1 being use of the given knowledge source. Then, 11 sources are added up, resulting in 0 if minimum and 11 if maximum. A firm with search

breadth of 11 is the most open toward innovation. On the other hand, search depth is how deeply a firm uses external source of information. Search depth is also measured by the combination of the 11 sources of information. First, 11 sources are coded 1 if a firm considers specific external source important and 0 if unimportant. In the questionnaire, the importance of use of external knowledge is measured on 5 point scale. I considered 4 and 5 important while 1-3 unimportant. Similar to the case of measuring search breadth 11 sources are added up to measure search depth, 0 being minimum and 11 being maximum.

Control variables

First, R&D intensity is controlled because internal R&D can have an impact on innovation performance. R&D intensity is measured as internal R&D expenditure divided by total sales of the firm. Given that many times innovation performance is led by users, the effect of client based external knowledge is controlled. Simply the variable takes 1 if the firm indicates the use of client based knowledge and 0 otherwise. Moreover, the firm size measured by the logarithms of the number of employees is controlled. Laursen and Salter (2006) control a start-up effect. Instead of controlling start-up effect, I control for the effect of firm age. Also, export is controlled because participating in export markets can promote

innovation (Cassiman and Golovko, 2011; Golovko and Valentini, 2011). Furthermore, collaboration is controlled because it is different from external search but it can affect innovation performance. Collaboration indicates whether or not the firm engaged in collaborating arrangement on innovation activities. Government support is coded 1 if there is governmental support and 0 otherwise. Finally, 23 industry controls are included to account for different propensities to innovate across industries.

Estimation

The dependent variable in the regression model is censored because the variable is the percentage of innovative sales from new products. By definition, the dependent variable ranges between 0 and 100. Thus, a Tobit analysis (Tobin, 1958) is applied. Tobit models are suitable for censored data. Tobit uses econometrics assumptions that there is a latent variable. A latent variable linearly depends on independent variable via a parameter which determines the relationship between the independent variable and the latent variable. The standard Tobit model assumes normal distribution of standard errors.

RESULTS

Table1 shows descriptive statistics of the data. Mean of

radical innovation is 8.89%, meaning that about 8.89% of sales come from "the new to world" products. As mentioned earlier, incremental innovation is divided into two types. Approximately 23.37 % of sales are derived from "new to firm" product innovation. 67.74% of sales are composed of "products significantly improved". Thus, sales from radical innovation and incremental innovation add up to 100%. Mean of speed is 14.69 months, meaning that it takes about 15 months to develop new product. Development of new product can take up to 180 months. Also, one firm usually draws knowledge broadly from 6.85 sources out of 11 sources. However, it is noticeable that one firm draws knowledge deeply from only 2.28 sources. In addition, correlations are displayed in Table2. It is not likely that there is multi-collinearity problem in this model.

Table1. Descriptive statistics

	No. of firms	Mean	S.D.	Min	Max
Radical_NTW	1353	8.89	18.04	0	100
Incremental_NTF	1353	23.37	22.90	0	100
Incremental_PSI	1353	67.74	27.99	0	100
Speed	1353	14.69	14.38	0.50	180
Breadth	1353	6.85	3.45	0	11
Depth	1353	2.28	2.30	0	11
R&D intensity	1353	0.08	0.19	0	3.52

Client	1353	0.84	0.36	0	1
Firm size	1353	4.42	1.38	1.99	10.13
Firm age	1353	19.97	13.74	4	84
Export	1353	0.60	0.49	0	1
Collaboration	1353	0.41	0.49	0	1
Government	1353	0.47	0.50	0	1

Statistical results of Tobit regression analysis can be found in Table3. Model 1-3 tested the hypotheses on the novelty of innovation. Model4 describes the results related to the innovation speed. First, strong support is shown for hypothesis1 asserting that external search depth is positively related to radical innovation performance. The parameter for external search depth is positive and significant at $p<0.01$. This result shows that external search depth is important for radical innovation which involves development of "new to world" products. This can be interpreted as the following statement. If firms want to radically innovate, sourcing knowledge deeply is crucial.

Second, contrasting results are shown on hypothesis2 asserting that external search breadth is positively related to incremental innovation performance. If a firm draws knowledge broadly from external sources of information, the firm is likely to show incremental innovation which involves "new to firm" products. The parameter of incremental innovation in regards to

Table2. Correlations

	1	2	3	4	5	6	7	8	9	10	11	12
1.Radical_NTW	1.00											
2.Incremental_NTM	−0.09*	1.00										
3.Incremental_PSI	−0.58*	−0.77*	1.00									
4.Speed	0.05	−0.02	−0.02	1.00								
5.Breadth	0.08*	0.01	−0.06*	0.18*	1.00							
6.Depth	0.11*	−0.01	−0.07*	0.12*	0.51*	1.00						
7.R&D intensity	0.10*	0.04	−0.10*	0.12*	0.01	0.02	1.00					
8.Client	0.08*	−0.01	−0.04	0.10*	0.63*	0.32*	0.01	1.00				
9.Firm size	−0.02	−0.09*	0.09*	0.15*	0.32*	0.23*	−0.15*	0.11*	1.00			
10.Firm age	−0.06*	−0.09*	0.11*	0.11*	0.18*	0.10*	−0.14*	0.10*	0.53*	1.00		
11.Export	0.04	−0.05*	0.02	0.11*	0.21*	0.16*	−0.01	0.12*	0.36*	0.23*	1.00	
12.Collaboration	0.04	−0.05	0.02	0.15*	0.29*	0.23*	0.05	0.14*	0.20*	0.07*	0.15*	1.00
13.Government	0.03	0.014	−0.03	0.15*	0.28*	0.24*	0.16*	0.17*	0.12*	0.01	0.19*	0.24*

t statistics in parentheses * $p < 0.05$

"new to firm" product development is positive and significant at $p<0.05$. However, hypothesis2 is partially supported because in the case of "product significantly improved", sourcing knowledge broadly can show negative effects. The parameter of incremental innovation involving "product significantly improved" is negative and significant at $p<0.05$.

Hypothesis3 claiming that external search breadth is negatively related to innovation speed is strongly supported at $p<0.05$. This result means that the speed of new product development can slow down if external search breadth is broad. The parameter of breadth is positive and significant at $p<0.05$. The parameter is positive because innovation speed was measured by how many months it took to develop new products. Hypothesis4 affirming that the more deeply the firm uses external source of knowledge, the more rapid the product development will be finds no support.

Table3. Regression results

	Model1	Model2	Model3	Model4
	Radical_NTW	Incremental _NTM	Incremental _PSI	Speed
Breadth	0.597	0.597*	−0.662*	0.361*
	(1.14)	(2.03)	(−2.00)	(2.29)

	(2.71)	(−0.17)	(−1.66)	(0.56)
R&D intensity	11.82	−0.523	−6.388	6.878***
	(1.90)	(−0.14)	(−1.50)	(3.38)
Client	6.813	−3.361	0.954	−0.0181
	(1.51)	(−1.38)	(0.35)	(−0.01)
Firm size	0.433	−1.376*	1.476	0.824*
	(0.37)	(−2.06)	(1.96)	(2.29)
Firm age	−0.104	−0.00311	0.0946	0.0350
	(−0.98)	(−0.05)	(1.39)	(1.08)
Export	4.194	−2.508	1.297	−0.220
	(1.52)	(−1.60)	(0.73)	(−0.26)
Collaboration	3.169	−2.643	2.229	1.391
	(1.23)	(−1.77)	(1.33)	(1.74)
Government	2.851	0.339	0.142	1.551
	(1.10)	(0.23)	(0.08)	(1.94)
Constant	−16.09*	28.82***	54.75***	3.837
	(−2.13)	(6.58)	(11.08)	(1.64)
Industry effects	yes	yes	yes	yes
No. of observations	1353	1353	1353	1353
No. of left−censored	849	131	57	0
No. of right−censored	9	25	5	0
Log likelihood	−2938.81	−5709.42	−6222.99	−5424.21
Chi−square	99.38***	66.74***	110.78***	203.70***
Pseudo R^2	0.0166	0.0058	0.0088	0.0184

t statistics in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001

DISCUSSION AND CONCLUSIONS

"Successful innovation requires tracking your partners and potential adopter as closely as you track your own development process" (Adner, 2006). Since Chesbrough (2003) brought up the idea of open innovation, many studies have tried to examine whether open innovation is effective in increasing innovation performance. Firms that are too internally focused may lose opportunities to learn from outsiders. Open innovation may broaden the firm's technologies and practices by externally sourcing knowledge. Thus, it is important to balance internal learning and external learning (Su et al., 2009). Firms can learn from customer, supplier, competitor and university. Variety search channels can provide rich ideas which can be applied in new product development. According to Barge-gil (2010), there are open, semi-open, and closed innovation strategies. However, how much the firm should be open to external sources of knowledge is still on debate. By bringing the concepts of search breadth and depth, Laursen and Salter (2006) examined how search breadth and depth can affect innovativeness of the firm. This paper extends the study of Lausen and Salter (2006) and contributes to the open innovation literatures in regards to search behavior.

I find that external search depth is positively related to radical innovation performance. Because resources of the firm are limited, focusing on learning from several sources deeply is

effective for radical innovation. Moreover, employees can overcome NIH syndrome, the hostile attitude toward external learning. Employees tend to feel fear from learning external sources and resist in accepting the changes driven by outside sources. If employees focus on learning deeply from several sources, they can overcome NIH syndrome. On the other hand, external search breadth is positively related to incremental innovation performance. Since resources of the firm are limited, broad range of external learning may not be effective. Thus, external search breadth is positively linked to incremental innovation rather than radical innovation. However, I find contrasting results for two types of incremental innovation. Although external search breadth is positively related to incremental innovation involving "new to firm" innovation, it is negatively related to incremental innovation involving "product significantly improved". Further study is needed to define what incremental innovation is. Should "product significantly improved" also be defined as incremental innovation? Or future research could divide incremental innovation into several categories and set different hypotheses for more detailed types of incremental innovation.

In addition, I find that external search breadth is negatively related to innovation speed. Resource allocation with limited resources may be the reason why searching too broadly might slow

down the innovation speed. However, no support is shown for hypothesis4 asserting that external search depth is positively related to innovation speed. This result shows there may be another factor affecting the innovation speed besides limited resources. Although firms may be focused when extracting knowledge deeply from several sources, some other factors such as communication problem may affect the innovation speed. In other words, the speed of innovation can lengthen when there is a lot of communications and discussions due to deep sourcing of external knowledge.

Limitations and future research

The analysis of the effects of external search breadth and depth on the novelty of innovation and the speed of innovation is based on data of KIS. KIS is similar to CIS which many open innovation researchers commonly use to conduct research (Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010; Klingebiel and Rammer, 2014). Both KIS and CIS use survey methods which may have bias. In natural, survey methods can be subjective. However, the sample size of this research is large enough to offset some drawbacks of survey methods. In future research, scholars can complement by using other methods such as patent analysis to conduct open innovation research. At the sub-firm level analysis of open innovation, co-patenting can be

used as a measure of collaboration with competitors, suppliers, universities. (Belderbos *et al.*, 2010; Belderbos *et al.*, 2014).

Deep knowledge domains may create inertia and may constrain firms to established technology (Tripsas and Gavetti, 2000). Especially this phenomenon can happen if firms use similar in-depth knowledge source for too long time. Other scholars have warned the inertia from drawing knowledge from too many sources (Katila and Ahuja, 2002; Laursen and Salter, 2006). However, my findings did not reflect this idea of inertia. I think inertia is related to repeated learning rather than learning from diverse sources of information. Further research has to be conducted to find whether inertia is related to repetition or diversity of sources.

Future studies can expand open innovation research by examining resource based view. Allocating resources to a broad scope of innovations increases new product innovation performance (Klingebiel and Rammer, 2014). However, handling various sources can be costly. Thus, it would be worth studying both benefits and disadvantages of allocating resources to various sources. Although I adopted the resource based view in this research by showing limited sources can delay innovation speed and hamper novel innovation, more detailed measure could be used to reflect resource based view in open innovation literatures. Also, there may be

difficulty in implementation of new product development because employees may have conflicts in implementing new knowledge which is noted by NIH syndrome. Future research can use more direct measures to see NIH syndrome. Implementation path of open innovation depends on the innovation needs, timing of innovation, and organizational culture (Mortara and Minshall, 2011) as well.

Furthermore, future research can find about unknown moderators affecting open innovation performance. Zhou and Li (2012) suggested that the impact of external search breadth and depth on innovation performance differs in the contexts of market knowledge acquisition and internal knowledge sharing. Open innovation activities are more important in turbulent environment (Schweitzer et al., 2011). Sofka and Grimpe (2010) argued that managers show selective search behavior rather than random search behavior. Further studies can explore in which environment mangers show certain search patterns. Sometimes, organizational design can affect the exploitation of external resources (Foss et al., 2013). Thus, the role of organizational design in open innovation should be further examined as well. Working with intermediaries can facilitate the successful open innovation (Lee et al., 2010).

Implications for managers

There are practical implications for managers who try to use

open innovation strategies. Applying open innovation strategies depend on the firm's goal. It is important for mangers to align the open innovation strategies with the firm's goal. In my findings, external search breadth and depth have different impacts on innovativeness of the product. In specific, search breadth is related to incremental innovation while search depth is related to radical innovation. Thus, if the goal of the firm is to introduce "new to world" products, it is better to learn deeply from several external sources of information. In contrast, if the goal of the firm is to develop "new to firm" products, the firm should focus on using knowledge from diverse sources.

In addition, managers should think about innovation speed in product development. Considering the average product life cycle of the market is important in winning from competition. Developing new product faster than competitors can be advantageous in achieving first mover advantage. First mover in the market can set standard of the market and build up strong brand image. Thus, speeding up the new product development is crucial. According to my findings, sourcing too broadly can slow down the speed of innovation. It is important for managers to consider the innovation speed and product life cycle at the same time to be competitive in the market.

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국문초록

Chesbrough (2003) 가 그의 저서에서 “오픈이노베이션” 이라는 개념을 제시한 이래 많은 기업은 오픈이노베이션 전략을 사용하기 시작했다. 본 연구는 외부지식의 탐색이 혁신성과와 혁신속도에 미치는 영향에 대해 연구하였다. 과학기술정책연구원(STEPI)에서 제공하는 2010년도 기술혁신활동조사표를 바탕으로 1353개 한국 제조기업을 실증분석 하였다. 깊이 있는 외부지식의 탐색은 급진적인 혁신성과와 양의 상관관계를 보였다. 반면, 다양한 외부지식의 탐색은 점진적인 혁신성과와 양의 상관관계를 보였다. 다양한 외부지식의 탐색은 혁신속도와 음의 상관관계를 보였다. 이러한 결과는 외부지식 탐색 전략이 기업의 목표와 일치하는 것이 중요하다는 점을 시사한다. 깊이 있는 탐색과 다양한 탐색은 기업이 “세상에 새롭게 선보이는 제품”을 출시할 것인지 “기업에 새롭게 선보이는 제품”을 출시할 것인지 그 목표에 따라 다르다. 본 연구는 기업이 오픈이노베이션 전략을 실행함에 있어 혁신성과뿐만이 아니라 혁신속도 또한 고려해야 한다는 점을 시사한다.

주요어: 오픈이노베이션, 외부지식의 탐색, 혁신성과, 혁신속도

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