External Knowledge search and Innovation: A Reverse Causation Hypothesis

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ABSTRACT *The breadth of external knowledge search has frequently been studied as an important antecedent of innovation, especially when the internal resources of a firm are insufficient and the industry environment is changing rapidly. In this paper we argue that the reverse could also be possible: that innovation could broaden knowledge search because innovative firms have higher absorptive capacity which in turn enables them to conduct and benefit from a broad search strategy. Based on a panel dataset of Korean firms, we found a positive relationship between prior breadth of external knowledge search and subsequent innovation mediated by absorptive capacity. The mediating relationship is negatively moderated by the extent to which firms belong to a business group and positively moderated by the high technology nature of the industry.*

Key words: search breadth, absorptive capacity, innovation, business group, high technology industry

INTRODUCTION

How can a firm be innovative? One answer is to look for more external knowledge to complement the existing knowledge base of a firm (Laursen, 2012; Leiponen & Helfat, 2010). External knowledge sourcing provides new ideas that are crucial for innovation. Activities such as R&D outsourcing, acquisition, and alliance taped into the external pool of potentially useful knowledge for innovation (Ahuja & Katila, 2001; Veugelers & Cassiman, 1999). External sourcing strategy differs in both depth and breadth. In general, deeper involvement of external knowledge sourcing enables closer interaction between knowledge sender and receiver, and allows transfer of tacit knowledge for innovation (Santamaria, Nieto, & Barge-Gil, 2009). Breadth of external knowledge sourcing is the number of external sources or search channels that firms rely upon for innovation (Laursen & Salter, 2006: 134). Firms may conduct either a broader or a narrower search breadth at a particular degree of search depth.

The role of search breadth as an enabler of innovation has been repeatedly proposed and verified in the literature. Fundamentally, searching broadly for knowledge tends to help innovation because of the variety in knowledge it provides to a firm (Laursen, 2012). Search breadth allows access to more variety of knowledge that increases new combinations of knowledge (Wuyts, Dutta, & Stremersch, 2004). A firm that engage in broad search becomes a "knowledge brokerage" (Hargadon & Sutton, 1997) and have a "radar function" (Duysters & Lokshin, 2011) to connect disparate knowledge. Search breadth also provides access to wide variety of technological capabilities which complement existing capabilities of the firm (Faems et al., 2010). Finally, search breadth increases the

odds of stumbling onto useful knowledge in an otherwise difficult to achieve situation (Leiponen & Helfat, 2010; Mol & Birkinshaw, 2009; Prabhu, Chandy, & Ellis, 2005). For these reasons, search breadth is seen to increase innovation. On the other hand, some research has started to look into negative consequences of search breadth such as increased complexity, management cost and appropriability concerns, and examines a diminishing return of excessive search breadth on innovation (Chen at al., 2011; Duysters & Lokshin, 2011; Laursen & Salter, 2006).

The assumption about causality underlying these research studies is that search breadth precedes innovation. Hence, research on search breadth and innovation has so far focused on innovation as the dependent variable. However, not every firm can search broadly and benefit from external linkages (Arora & Gambardella, 1994; Laursen, 2012). Search breadth could itself be an endogenous construct. A different and potentially useful research question is, would innovation generate search breadth? This is the question we address in this research.

Based on the literature on knowledge transfer, we develop a model to study the possibility of innovation causing search breadth. What is worth noting is that, we are not suggesting that the current assumption about knowledge search causing innovation is wrong, only that the reverse could also be true. While knowledge search increases innovation, higher innovation may induce broader search. If this is true, a firm could create a virtuous cycle by either investing in more innovation or a broader knowledge search. We test this reverse causation idea with a panel data of 102 Korean manufacturing firms. These firms have responded to three waves of Korean Innovation Survey (KIS) in 2002, 2005, and 2008, allowing a time lag between search breadth and innovation to test our hypotheses.

Examining this possibility of reverse causation addresses both academic interest and managerial concern on how to manage innovation and knowledge in organization. We aim to make two main contributions to the literature in this paper. First, we extend current literature to show that innovation could impact search breadth. Further, we argue that the strength of such impact increases if firms operate in hi-tech industries or do not belong to a business group. In sum, this work provides insights into how a firm's innovation and knowledge search affect each other, and advocate a virtuous cycle of innovation and knowledge search that have important implications for managers.

THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

We look at search breadth as the outcome of the knowledge transfer process between a firm, as a knowledge receiver, and its external partners (Inkpen & Tsang, 2007; Szulanski, 1996; Minbaeva, 2007). Specifically, we argue that innovative firms are more able to learn from external partners. Innovative firms will develop high absorptive capacity which in turn allows them to search broadly for knowledge. Business group and industry nature would affect the learning process as they affect motivation to learn and difficulty in tacit knowledge transfer respectively. We use arguments from organizational theory on absorptive capacity and the knowledge-based view, as well as recent works in knowledge transfer to develop our arguments on the role of innovation and learning in search breadth. These arguments highlight why innovation could be an antecedent of search breadth.

Three mechanisms are critical in determining the extent of search breadth of a firm. The first mechanism that facilitates search breadth is the learning ability of the knowledge receiver. The second mechanism is the relationship between knowledge sender and receiver (Inkpen & Tsang, 2009; Minbaeva, 2007). The third mechanism is the knowledge characteristics that would affect the difficulties of knowledge transfer (Minbaeva, 2007). These three mechanisms underlie the arguments of our hypotheses.

We firstly argue that innovative firms will conduct broader knowledge search. This is because innovative firms have the ability to access and utilize diverse external knowledge. Internal and external knowledge bases are considered complementary to each other (Cassiman & Veugelers, 2006). The large internal knowledge base that innovative firms possess enables them to identify and acquire diverse knowledge (Vega-Jurado, Gutiérrez-Gracia, & Fernández-de-Lucio, 2009), and provides them the experience to subsequently leverage the external knowledge with existing knowledge base (Wuyts & Dutta, forthcoming).

At the same time, innovative firms require more diverse knowledge as input for their innovation, as their internal knowledge base is insufficient for them to further increase their innovative outputs that are already at a high level. The ability of innovative firm to access and utilize diverse knowledge, coupling with the fact that they also require diverse knowledge for further innovation, mean that innovative firms tend to adopt a broad search breadth strategy. We therefore

propose that innovative firms will search for knowledge from a more diverse set of partners than firms that are less innovative.

Hypothesis 1: Innovation is positively related to external knowledge search breadth

We further argue that the knowledge searching process of innovative firms that results in a broad search breadth is mediated through a high absorptive capacity. Absorptive capacity is the ability of a firm to recognize the value of, assimilate, and apply external knowledge to use (Cohen & Levinthal, 1990). Absorptive capacity reflects the knowledge base of a firm (Escribano et al., 2009). It is often operationalized as the R&D/total employee ratio. Because of their active engagement and experience in innovation, innovative firms have a large knowledge base to absorb external knowledge. Firms with high absorptive capacity are, in turn, able to value and search for external knowledge, and are likely to conduct broad knowledge search. Arora and Gambardella (1994) find that firms with higher absorptive capacity are more able to utilize knowledge obtained from external partners, hence will enter into larger number of alliances. Fabrizio (2009) finds that activities that build up absorptive capacity will increase the value of external search for innovation.

Hypothesis 2: Absorptive capacity mediates the positive relationship between innovation and external knowledge search breadth

We also examine the moderating role of business group on the learning mechanism discussed above that leads to search breadth, and argue that business group affiliation would lessen the mediating role of absorptive capacity. Business group functions as an efficient market intermediation and encourage interfirm business transactions within group (Choi, Lee, & Williams, 2011). Firms that belong to business group are likely to interact and engage in knowledge transfer activities with external partners who belong to the same business group. Business group membership increases the motivation of a firm to seek knowledge from external partners. This is because there is an overarching group control system for business group partners (White, Hoskisson, Yiu, & Bruton, 2008). Expropriation concern over innovation is lowered for partners of the same business group. Moreover, within-group business ties are often closer and longer than extra-group business ties (Mahmood et al.,

2011). The closer and longer ties establish similarity in culture and practices with external partners, which enhance the willingness of firms to transfer knowledge. On top of within-group ties, business group membership increases the status of firms, allowing them to engage in more extra-group ties with firms outside the business group.

As the willingness to seek knowledge from external partners increases for firms that belong to a business group, the ability to seek external knowledge arising from absorptive capacity would play a lesser role on search breadth. In other words, given the same ability on knowledge transfer, innovative firms with business group membership would engage in broader search compared with firms without business group membership. The ability to transfer knowledge is substituted by a willingness and motivation to acquire and use more diverse external knowledge. Hence, based on our theoretical framework, we expect business group affiliation to weaken the mediating role of absorptive capacity between innovation and search breadth.

Hypothesis 3: The mediating effect of absorptive capacity on the innovation-search breadth relationship will be weaker for firms that affiliate with a business group than not affiliate with a business group.

Finally, we study the moderating role of industry nature and argue that absorptive capacity plays a stronger mediating role between innovation and search breadth for firms in high-technology than low-technology industries. High-technology and low-technology industries differ substantially in the tacitness of knowledge prevailing in the industry. Knowledge transfer in high-technology industry, such as biotechnology, pharmaceutical, and telecommunication, usually involves tacit knowledge related to advanced science and engineering problems (Williams, 2007; Zucker, Darby, and Armstrong, 2002). Tacit knowledge is difficult to transfer because it is ambiguous and non-codifiable (Minbaeva, 2007; Simonin, 1999). Because of the difficulty in transferring tacit knowledge in high-technology industries, it requires firms to equip with higher learning ability and more alliance experience to evaluate, absorb, and utilize external knowledge, and benefit from the knowledge transfer. Since innovative firms are higher in their ability and experience to learn, they have higher absorptive capacity to transfer tacit knowledge and therefore will engage in broader search breadth.

Fabrizio (2009) finds that absorptive capability is important for firms in the pharmaceutical and biotechnology industries to search for innovation. On the other hand, knowledge search in low-technology industries is more likely to involve explicit and codified knowledge. Knowledge transfer is relatively easy and does not rely heavily on a high absorptive capacity. Hence, based on our theoretical framework, high-technology industry strengthens the mediating role of absorptive capacity to convert innovation to search breadth.

Hypothesis 4: The mediating effect of absorptive capacity on the innovation-search breadth relationship will be stronger for firms in hi-tech industries than low-tech industries.

METHODS

Sample Context

We use a longitudinal sample of Korean manufacturing firms which participated in the Korean Innovation Survey (KIS) to test our hypotheses. The KIS was conducted by the Science and Technology Policy Institute in South Korea. Firms were randomly selected from the Korean manufacturing industries and many of the sampled firms are SMEs. Similar to its European counterpart Community Innovation Survey (CIS), the KIS questionnaires followed the Oslo Manual of OECD (see some recent examples in de Faria, Lima, & Santos, 2010; Duysters & Lokshin, 2011; Leiponen and Helfat, 2010, 2011). The surveys covered a large number of knowledge transfer and innovation activities. So far some KIS data have been used in innovation-related research, showing good reliability and validity of measures (e.g., Eom and Lee, 2010; Lee et al., 2010).

For our purpose, we construct a panel dataset using three waves of KIS surveys conducted in the years 2002, 2005, and 2008, respectively. The Science and Technology Policy Institute provided us the survey data of 102 firms which participated in all three surveys. Since we lagged the independent variables in the analysis, our panel data comprise 204 firm-year observations of 102 firms across three surveys. As each wave of survey asked questions about knowledge and innovation-related activities for the past two or three years before the survey time, the merging of three surveys creates a dataset that span a time period of eight years (i.e., 2000–2007).

Measure

For the panel data, we lagged absorptive capacity (i.e., mediating variable) and external knowledge search breadth (i.e., dependent variable). This lag is able to account for the delay of the effects of innovation, and also improve the accurateness of the causal inference by reducing the possibility of the simultaneity and endogeneity problems (Baum, 2006). Appendix 1 listed all the items of the measures used in this study.

External knowledge search breadth. We followed a common measurement of knowledge source breadth in the CIS studies to measure external knowledge search breadth in two steps (Cohen and Malerba, 2001; Duysters and Lokshin, 2011; Laursen and Salter, 2006; Leiponen and Helfat, 2010, 2011). In the first step, respondents were asked to rate the importance of nine information sources as a catalyst for innovation on a six-point scale from 0 (no use), 1 (not at all), to 5 (very high). The nine sources were worded differently in the three waves of survey but were comparable across surveys (as shown in Appendix 1). They included (1) competitors, (2) suppliers, (3) customers, (4) private service providers, (5) universities, (6) government and public research institutes, (7) external associations, (8) professional journals and books, and (9) exhibitions, conference, and trade shows. We coded each item as a dummy variable, assigned a value of 1 if the firm used a specific knowledge source (i.e., original score equal to 2 or above), and 0 if not, during the period of 2002-2004 (and of 2005-2007). In the second step, we added the values of each binary item to form a score for external knowledge search breadth. Thus, in a specific year, a firm's external knowledge search breadth would score 0 when none of the knowledge sources was used and 9 when all of the nine knowledge sources were used.

Innovation. Innovation was measured as the sum of five dichotomized variables on (1) incremental product innovation, (2) radical product innovation, (3) process innovation, (4) organizational innovation, and (5) marketing innovation. Respondents were asked whether their firms had generated each type of innovation. It was coded 1 if a firm generated the focal innovation, and 0 if not. A firm would score 0 if it did not generate any innovation, and 5 if it produced all five types of innovation.

As the exact wording of the items on innovation was different for the 2002 and 2005 questionnaires, we re-categorized these items so that the measurements were consistent across the two surveys (as shown in Appendix 1).

Absorptive capacity. Absorptive capacity is the capacity of a firm to absorb new knowledge. The KIS did not contain any item that directly measures this capacity. We adopted the log transformed number of R&D employees as the proxy of absorptive capacity, similar to Liu and White (1997) and others. We used in our analyses the year-2001 and year-2004 data of R&D employees, which were collected from the 2002 and 2005 questionnaire surveys, respectively.

Business group. Business group is measured as a dummy variable, coded 1 if a firm was affiliated with a domestic group company, and coded 0 otherwise.

Industry. A dummy variable was created to measure industry. Firms were categorized into high-tech vs. low-tech industries, based on the Korean Standard Industry Classification (KSIC) in 2002. The high-tech industries include petroleum products/nuclear energy, chemical products, machinery/equipment, office/computing equipment, other electric machinery/conversion systems, visual/sound/telecommunication devices, medical/precision/optical equipment/watch, automobiles/trailers, and other transport equipment. The low-tech industries included: food/beverage, garment, wood products, footwear/bags, printing, plastic, non-metal mineral products, primary metal, and fabricated metal (excluding machinery/equipment). High-tech industry was coded 1 and low-tech industry 0.

Control variables. We controlled for firm age, firm size, and financial performance that have been showed to affect knowledge search breadth in previous research. Specifically, *firm age* was calculated by subtracting the founding year of a firm from the survey years 2002 and 2005. *Firm size* was measured as the total sales in years 2001 and 2004. *Financial performance* was measured by the return on sales in years 1999 and 2002.

Analytical method

We use the generalized estimating equations (GEE; Liang and Zeger, 1986) to analyse the effect of innovation on external search breadth in the panel data. We choose a GEE model because

this technique allows for the modelling of correlated observations within firms resulting from the repeated measures across years (c.f., Chan, Isobe, and Makino, 2008; Diestre and Rajagopalan, 2011; Wowak, Hambrick, and Henderson, 2011). Our estimations were based on unstructured matrix, which places least restrictions on the model estimations (Ballinger, 2004) and thus has less statistical biases caused by testing techniques. All the data analyses were conducted in the STATA package, mostly with its panel GEE 'xtgee' function.

RESULTS

The descriptive statistics of variables and correlation matrix between them are reported in Table 2. The results of panel regressions are presented in Tables 3–5.

[Insert Table 2 about here]

Hypothesis 1 predicts that the innovation will positively affect external knowledge search breadth. Model 2 in Table 3 shows that the coefficient of innovation is statistically significant and positive in sign ($B = .24$, $p < .05$). Thus, Hypothesis 1 is supported.

Hypothesis 2 suggests that absorptive capacity mediates the effect of innovation on external knowledge search breadth. We tested this mediating effect using Baron and Kenny's (1986) approach. To confirm the mediation, we are required to meet three conditions: (1) in the regression of external knowledge search breadth on innovation, innovation is statistically significant; (2) in the regression of absorptive capacity on innovation, innovation is statistically significant; (3) when innovation and absorptive capacity both enter the regression of external knowledge search breadth, absorptive capacity is statistically significant, yet innovation becomes insignificant (in the complete mediation) or weaker in magnitude (in the partial mediation). The results of Hypothesis 1, shown in Model 2, have provided supports for the first condition. Model 3 reveals that the effect of innovation on absorptive capacity was significant and positive ($B = .14$, $p < .001$), which was in line with the second condition of mediation. In addition, Model 4 shows that the effect of absorptive capacity on external knowledge search breadth was significant and positive ($B = .55$, $p < .01$), yet that of innovation was reduced to insignificant, which was consistent with the third condition. These results thus indicate a complete mediation of absorptive capacity in the effect of innovation on external knowledge search

breadth. In addition to the Baron and Kenny's (1986) test, we also ran a Sobel test, which confirmed the significance of the mediating effect (ab path = 2.25, $p < .05$). Therefore, Hypothesis 2 was supported.

[Insert Table 3 about here]

As the proposed moderators (business group and industry) are binary variables in Hypotheses 3 and 4, we employ sub-group comparison to test the moderating effects. We firstly tested Hypothesis 3 on the moderation of business group. For firms affiliated with business group, the three conditions of mediation according to Baron and Kenny (1986) were not all met. Particularly, Model 6 (in Table 4) failed to find a significant overall effect of innovation on external knowledge search breadth (B = -.04, p > .10) and thus was unable to meet the first condition of mediation. The results implied that absorptive capacity did not mediate the relationship between innovation and external knowledge search breadth.

In contrast, for firms not affiliated with any business group, the mediation of absorptive capacity was significant. Innovation was significantly and positively associated with external knowledge search breadth (B = .27, p < .05, as shown in Model 10) and absorptive capacity (B = .14, p < .01, as shown in Model 11). Moreover, when innovation and absorptive capacity were entered into the same regression of external knowledge search breadth, the effect of innovation became insignificant, while the effect of absorptive capacity remained significant and positive (B = .62, p < .01, as shown in Model 12). The results of Sobel test further confirmed the mediating role of absorptive capacity (Sobel test statistic = 2.07, p < .05). These results showed that absorptive capacity fully mediated the effect of innovation on external knowledge search breadth in non-group firms.

Based on the above results, we can draw the conclusion that the business group moderates the mediating effect of absorptive capacity on the relationship between innovation and external knowledge search breadth. Hence, Hypothesis 3 was supported.

[Insert Table 4 about here]

For high-tech industry, Models 14–16 in Table 5 show generally evidence for the mediating effect of absorptive capacity. Model 14 shows an overall positive impact of innovation on external

knowledge search breadth (B = .41, p < .01). In addition, Model 15 reveals that the influence of innovation on absorptive capacity was significant (B = .18, p < .001). Finally, Model 16 exhibits that, when the effects of absorptive capacity and innovation were estimated simultaneously, absorptive capacity had a significant impact on external knowledge search breadth while innovation did not. The results met the three conditions of mediation suggested by Baron and Kenny (1986). Therefore, absorptive capacity mediates the effect of innovation on external knowledge search breadth in high-tech industry.

In contrast, the mediating effect of absorptive capacity was not supported for low-tech industry. Neither the impacts of innovation on external knowledge search breadth (shown in Model 18) and on absorptive capacity (in Model 19) were significant, nor was the effect of absorptive capacity on external search breadth (in Model 20). Hence, for low-tech industry, absorptive capacity did not mediate the effect of innovation on external knowledge search breadth. A comparison of the above results between high-tech and low-tech industries implies that industry moderates the relationships between innovation, absorptive capacity, and external knowledge search breadth. Therefore, Hypothesis 4 was supported.

[Insert Table 5 about here]

DISCUSSION AND CONCULSIONS

This paper finds that innovation increases external knowledge search breadth through absorptive capacity. Furthermore, this mediating effect is moderated by business group and industry. Specifically, the mediation is only significant for firms without a business group affiliation, or firms in high-tech industries.

This paper provides theoretical contributions to both knowledge search and innovation literature. On the study of knowledge search, we extend current research to develop a model of knowledge search breadth based on learning ability, motivation, and difficulty of knowledge transfer. On the study of innovation, we showed that innovation is not only a consequence of knowledge search

as found in the existing literature, but may also serve as a precursor to knowledge search strategy. Thus, we add an important outcome of innovation that has seldom been studied.

The findings are also important to practicing managers. Knowledge search strategy is crucial in turbulent environment, as firms involve in broader knowledge search can keep themselves alert and aware of what is happening in the business environment. This paper suggests that being innovative might be a way to broaden knowledge search outside of firms. Innovativeness and knowledge search might fuel a virtuous cycle. Importantly, we find in this study that innovation is more likely to increase the breadth of knowledge search when a firm is not affiliated with any business group and when a firm is in high tech industry. Managers should pay attention to these environmental constraints when devising their innovation and knowledge search strategy.

The contributions of this study should be viewed in light of some limitations, which at the same time, points to future research opportunities. First, the Korean sample enables us to examine the influence of business group, but at the same time may limit the generalizability of our findings to other countries. Hence, more replications are needed to further verify the results found in this study. In addition, the motivation of knowledge search and the characteristics of knowledge are only indirectly measured via proxy variables, i.e., business group and industry, respectively. It would be valuable to adopt some direct measures so that the relationships of interest shall be examined with less bias. Finally, we only studied knowledge search breadth in this study.

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Appendix 1

Table 1 Item measurements

Variables	Items in 2002 survey	Items in 2005 Survey	Items in 2008 Survey
External knowledge search breadth Each item in the survey was coded 1 if the source of knowledge was used, and 0 if not. The value of external knowledge search breadth is the sum of the nine (dummy) items.		During 2002-2004, indicate the extent to which each of the following sources of information was used (for your company's technological innovation activities) on a scale (0 = no use, 1= very low, 5= very high).	During 2005-2007, the extent to which the following source of information was used (for innovation activity)? (0=not used, 1 = very low, 5 = very high)
		Competitors in the industry	Competitors in the same industry
		Suppliers (raw materials, software)	Suppliers
		Suppliers of machinery/equipment	
		Customers	Customers
		Business service providers (consulting, legal, accounting, etc.)	Private service providers (including consulting)
		University	Universities
		Government / national research institute	Government/Public (national) research institutes
		Non-profit organization (associations, cooperatives, chamber of commerce, etc.)	External associations (industry associations, cooperatives)
		Professional magazine	Professional journals / books
		Professional technology conference	Exhibitions, conference, trade shows
		Trade shows / Exhibitions	

Innovation Measured as the sum of five dummy variables listed on the right.	**1. Incremental product innovation** For 2000-2001, was there any technologically improved product (yes/no) Code 1 = yes, and 0 = no	**1. Incremental product innovation** How many significantly improved products to the market in 2002, 2003, and 2004, respectively? coded as 1 if there is any in any year, and 0 otherwise	
	2. Radical product innovation For 2000-2001, did it introduce a technologically new product/service (yes/no) Code 1 = yes, and 0 = no	**2. Radical product innovation** How many new products to the market in 2002, 2003, and 2004, respectively? coded as 1 if there is any in any year, and 0 otherwise	
	3. Process innovation For 2000-2001, was there any new process or significant process improvement (yes/no) Code 1 = yes, and 0 = no	**3. Process innovation** number of process innovation, i.e. new or significantly improved production or process logistics, purchase, accounting, etc., in 2002, 2003, and 2004, respectively coded as 1 if there is any in any year, and 0 otherwise	

	4. Organizational innovation For 2000-2001, is there any organizational innovation? (yes/no) Code 1 = yes, and 0 = no	**4. Organizational innovation** For 2002-2004, this firm introduced the following organizational innovation: 1) Significant change in learning/knowledge sharing (yes/no) 2) Change in production / Supply management (yes/no) 3) Change in task flexibility/interdepartmental integration (yes/no) 4) Outsourcing (function/department) (yes/no) 5) Change in external relationship with suppliers, customers, public organizations (yes/no) coded as 1 if the answer to any item above is yes, and 0 otherwise)	
	5. Marketing innovation For 2000-2001, is there any marketing innovation? (yes/no) Code 1 = yes, and 0 = no	**5. Marketing innovation** For 2002-2004, this firm introduced the following marketing innovation: 1) Significant change in the design/packaging of a good (yes/no) 2) Significant change to presentation in sales outlets/marketing concept/strategy (yes/no) 3) New marketing channel (mobile, TV, etc.) (yes/no)	

		coded as 1 if the answer to any item above is yes, and 0 otherwise)	
Absorptive capacity	log transformed number of R&D employees in 2001	log transformed number of R&D employees in 2004	
Business group	0 = not belong to a business group, 1 = belong to a business group		
Industry	KSIC (Korean Standard Industry Classification) was adopted and then recoded into high-tech vs. low-tech industries, specifically 1. Low-tech industries (food/beverage; garment; wood products; footwear/bags; printing; plastic; non-metal mineral products; primary metal; fabricated metal (excl. machinery/equipment) 2. High-tech industries (petroleum products/nuclear energy; chemical products; machinery/equipment; office/computing equipment; other electric machinery/conversion systems; visual/sound/telecommunication devices; medical/precision/optical equipment/watch; automobiles/trailers; other transport equipment) 0= low-tech and 1= high-tech		
Firm size	Total sales at the end of 2001 (in 100 billion won)	Total sales at the end of 2004 (in 100 billion won)	
Firm age	Years of operation (survey year 2002 minus founding year)	Years of operation (survey year 2005 minus founding year)	
Financial performance	Return on sales in 1999	Return on sales in 2002	

Table 2 Mean, Standard Deviation, and Correlations

	Mean	S.D.	1	2	3	4	5	6	7
1. Age	25.84	15.03							
2. Size	4.47	14.9	.11						
3. ROS	2.22	26.81	-.01	-.01					
4. Innovation	2.28	1.72	-.05	.15*	.03				
5. External knowledge breadth	5.37	2.77	-.03	.17*	-.03	.17*			
6. Absorptive capacity (ln R&D employees)	2.98	1.09	.15*	.31***	.05	.29***	.26***		
7. Industry (1=high tech)	.52	.50	-.04	.14*	.07	.14^{+}	.10	.32***	
8. Group (1=business group affiliation)	.21	.41	-.10	.13^{+}	.14^{+}	.13^{+}	.14*	-.06	-.11

N = 204
+ $p < .10$
* $p < .05$
** p < .01
*** $p < .001$

Table 3 Effect of Innovation on External Knowledge Search Breadth and the Mediating Role of Absorptive Capacity

Variables	Model 1 External knowledge search breadth	Model 2 External knowledge search breadth	Model 3 Absorptive capacity	Model 4 External knowledge search breadth
Intercept	5.44*** (.39)	4.87*** (.46)	2.34*** (.19)	3.62*** (.62)
Age	-.01 (.01)	-.01 (.01)	.009^{+} (.006)	-.01 (.01)
Size	.03* (.01)	.03* (.01)	.02** (.006)	.02 (.01)
ROS	-.003 (.007)	-.004 (.007)	.002 (.002)	-.005 (.007)
Innovation		.24* (.11)	.14*** (.04)	.15 (.11)
Absorptive capacity				.55** (.19)
Wald chi-square	6.33^{+}	11.65*	29.01***	21.03***

Table 4 GEE Regression Models Examining the Moderating Effect of Business Group

Variables	Business Group (N = 43)				Non-group (N = 159)			
	Model 5 External knowledge search breadth	**Model 6 External knowledge search breadth**	**Model 7 Absorptive capacity**	**Model 8 External knowledge search breadth**	**Model 9 External knowledge search breadth**	**Model 10 External knowledge search breadth**	**Model 11 Absorptive capacity**	**Model 12 External knowledge search breadth**
Intercept	5.59*** (.71)	5.71*** (.93)	1.46*** (.42)	4.18*** (1.09)	5.20*** (.47)	4.58*** (.54)	2.36** (.21)	3.13*** (.74)
Age	.03 (.03)	.02 (.03)	.01 (.01)	.03 (.03)	-.01 (.01)	-.01 (.01)	.01^{+} (.01)	-.02 (.01)
Size	-.002 (.02)	-.001 (.02)	.02* (.007)	-.02 (.02)	.05** (.02)	.05** (.02)	.02** (.007)	.03 (.02)
ROS	-.005 (.006)	-.005 (.006)	.003** (.001)	-.007 (.005)	.09 (.30)	.15 (.30)	.03 (.10)	.15 (.29)
Innovation		-.04 (.20)	.43*** (.07)	-.24 (.21)		.27* (.13)	.14** (.05)	.19 (.13)
Absorptive capacity				.74* (.32)				.62** (.22)
Wald chi-square	1.68	1.72	50.16***	7.52	8.51*	13.26*	25.02***	22.18***

Table 5 GEE Regression Models Examining the Moderating Effect of Industry

	High-tech industry (N = 106)				Low-tech Industry (N = 98)			
Variables	**Model 13 External knowledge search breadth**	**Model 14 External knowledge search breadth**	**Model 15 Absorptive capacity**	**Model 16 External knowledge search breadth**	**Model 17 External knowledge search breadth**	**Model 18 External knowledge search breadth**	**Model 19 Absorptive capacity**	**Model 20 External knowledge search breadth**
Intercept	6.05*** (.53)	5.04*** (.59)	2.33*** (.23)	3.05*** (.82)	4.40*** (.56)	4.35*** (.68)	2.40*** (.30)	3.60*** (.91)
Age	-.02 (.02)	-.02 (.02)	.02** (.007)	-.04* (.02)	.01 (.02)	.01 (.02)	.001 (.008)	.01 (.02)
Size	.03^{+} (.01)	.02^{+} (.01)	.01* (.005)	.008 (.01)	.19** (.06)	.19** (.06)	.03 (.03)	.18** (.06)
ROS	-.003 (.007)	-.005 (.007)	.002 (.002)	-.007 (.007)	-.27 (.34)	-.26 (.35)	.04 (.12)	-.27 (.34)
Innovation		.41** (.15)	.18*** (.05)	.27^{+} (.15)		.02 (.16)	.05 (.06)	-.001 (.16)
Absorptive capacity				.86** (.27)				.32 (.26)
Wald chi-square	4.79	14.49**	34.17***	28.23***	9.97*	10.01*	1.87	11.49*