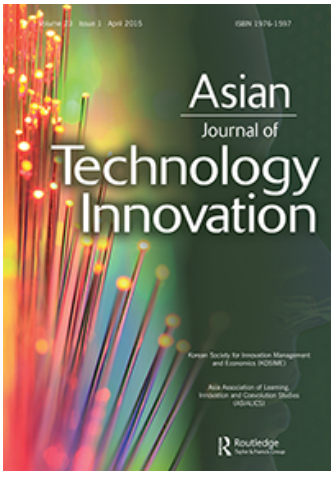

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External technology acquisition: a double-edged sword

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External technology acquisition: a double-edged sword

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Firms are known to actively utilise external technology acquisition to update and extend their technological knowledge base. Although external technology acquisition has various advantages, it should be considered as a double-edged sword as it also has some inherent negative aspects. This study examines the role of external technology acquisition to investigate whether external technology acquisition is complementary or substitutive to internal R&D activities in creating innovation. The results show that external technology acquisition has an inverted U-shaped relationship with subsequent technology innovation performance, and that is not complementary to internal R&D activities. We thus confirm that external technology acquisition has to be seen as a double-edged sword and that managers need to be aware of the potentially negative effects of strong diversity of the firm's external technology acquisition sources on internal R&D and subsequent innovation performance.

Keywords: external technology acquisition, technological innovation, absorptive capacity, R&D, knowledge base

1. Introduction

Faced with accelerating changes of the technological environments and increasing international competition, firms need to possess the ability to timely update their technological knowledge base in order to survive (D'Aveni 1994; Foster and Kaplan 2001; Lin and Wu 2010). However, it is impossible for firms to keep up with all the relevant technological knowledge by relying solely on internal R&D (Horwitch 1986; Teece 1986; Burgelman and Rosenbloom 1989; Chesbrough 2003). Firms inevitably utilise external sources as a means of enhancing innovative performance and reinforcing competitive advantage. In the last years, external technology acquisition has received more and more interest from relevant literature (Chesbrough 2003; Kang and Kang 2009; Rothaermel and Alexandre 2009; Lin and Wu 2010).

External technology acquisition is known to possess a variety of advantages. It allows firms to acquire the best available technology, reduce time to market, and focus their resources and capabilities on core technological competencies (Lowe and Taylor 1998; Veugelers and Cassiman 1999; Tiwana and Keil 2007). Moreover, recent studies have emphasised that external sourcing is complementary to internal R&D or the existing knowledge base in developing new products and enhancing firm performance (Caloghirou, Kastelli, and Tsakanikas 2004; Rothaermel and

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Alexandre 2009; Lin and Wu 2010). The open innovation paradigm has also supported the importance of utilising external knowledge and technologies for successful innovation and competitive advantage (Chesbrough 2003).

However, one has to look beyond the obvious advantages of external technology acquisition for competitive advantage and internal R&D. There is a strategic substitutability between external sourcing and internal R&D in terms of obtaining the necessary technological knowledge for innovation. Under the condition of limited resources, an increase in spending for external technology acquisition naturally causes a decrease in internal R&D expenditure. It may generate negative consequences for the firms' core technological competences and the firms may actually lose their long-term competitive advantage (Sen and Rubenstein 1989; Quinn 1992). This substitutive relationship between external sourcing and internal R&D has been confirmed by a number of previous empirical studies (Blonigen and Taylor 2000; Higgins and Rodriguez 2006; Laursen and Salter 2006; Watkins and Paff 2009). Therefore, external technology acquisition should be considered as a double-edged sword.

The study examines the role of external technology acquisition in creating innovation and investigates whether external technology acquisition is complementary or substitutive to internal R&D activities. We first capture the extent of external technology acquisition using the concept of 'breadth', and investigate its impact on subsequent technological innovation. Thereafter, we confirm the effects of two major components of internal R&D – internal R&D activities and existing knowledge base – on subsequent technological innovation. Finally, we test the interaction effects of the breadth of external technology acquisition and the two components of internal R&D on the firms' subsequent innovation.

We employed a survey data-set (1152 subsamples) on the technological knowledge-sourcing activities of South Korean firms in 2007. The subsequent technology innovation performance was measured by the number of patents in the 2008–2010 timeframe. This paper is organised into four sections. Section 1 establishes the theoretical framework of the research through a literature review and presents our hypotheses. Section 2 outlines the employed data-set and describes the method of analysis. Section 3 presents the results and in Section 4, we conclude with a discussion on the limitations of our approach and recommendations for further research.

Our key finding is that external technology acquisition is not always advantageous for firms and is not always complementary to internal R&D activities in creating innovation. The findings confirm that external technology acquisition has to be seen as a double-edged sword for competitive survival. Firms are advised to utilise external technology acquisition at a moderate level and find a balance between external technology acquisition and their internal R&D activities.

2. Conceptualisation and hypotheses

2.1. *External technology acquisition*

2.1.1. *External technology acquisition: a double-edged sword*

External technology acquisition provides several advantages to firms. First, it helps them to overcome limitations of their internal resources and capabilities. By sourcing technology externally, firms can overcome internal knowledge deficiencies and resolve problems of insufficient internal resources and capabilities (Lowe and Taylor 1998; Veugelers and Cassiman 1999; Park and Kang 2010; Du, Wu, Lu, and Yu 2013). It also allows firms to acquire industry standard technologies and complements for existing products, and to unlock existing technology and innovations (Lowe and Crawford 1984), and thus helps firms catch up with competitive moves or fill market gaps (Lowe and Taylor 1998).

Second, by outsourcing non-core technological activities, external technology acquisition allows firms to focus their resources and capabilities on developing their core technological competencies (Tiwana and Keil 2007). External technology acquisition allows firms to specialise deeper in their core competences while relying on outside firms that are specialised in other fields, for complementary expertise and skills (Grant and Baden-Fuller 2004).

Third, external technology acquisition provides flexibility in strategic decision-making for technology development. Although it may be difficult for firms to adapt to unfamiliar technological areas due to comfort in using previous technological paths (Dosi 1982), firms can readily acquire background knowledge on new technological areas through external technology acquisition, thereby increasing the speed of adapting to new technologies. In addition, if external technology acquisition is effectively pursued, firms can benefit from a larger range of technological solutions and hence take advantage of new business opportunities (Mowery and Rosenberg 1989).

However, heavy reliance on external technology acquisition may have disadvantageous consequences. The most critical risk of external technology acquisition is the trade-off between external technology acquisition and internal R&D in terms of obtaining necessary technological knowledge and capabilities. Winter (1987) and Prahalad and Hamel (1990) emphasise that firms develop key competencies or assets from previous R&D investments and 'learning by doing'. These core competencies can be viewed as resources and capabilities, as well as knowledge sets, accumulated by firms over time to gain competitive advantage. Available resources and capabilities for technological sourcing are limited; hence, the more resources firms invest in external technological acquisition, the less they are able to invest in internal R&D. Heavy reliance on external technology acquisition may therefore decrease the internal R&D capabilities of firms, ultimately weakening their core technological competencies (Sen and Rubenstein 1989; Quinn 1992). This increases the risks of becoming hollow and losing competitive advantages (Miles and Snow 1992; Dodgson 1993).

Additionally, factors such as the not-invented-here (NIH) syndrome or the lack of absorptive capacity may lead to inefficiencies of the external technology acquisition process. The NIH syndrome is the tendency of a project group of stable composition to believe that it has absolute knowledge in its field, leading to resistance to externally sourced new ideas and knowledge (Katz and Allen 1982). The NIH syndrome suggests that focussing on external technology acquisition may result in internal resistance from the technical staff of firms. Even if this resistance can be overcome, successful users of externally sourced technology are required to maintain significant absorptive capacity for assimilating the external technologies to their internal needs (Cohen and Levinthal 1990; Rosenberg 1990). Firms that rely heavily on external technology acquisition may lose absorptive capacity, and thus may find it increasingly difficult to assimilate external knowledge and successfully utilise it for new technological developments.

Another issue arises from the features of externally sourced knowledge. Knowledge and technology have context-dependent features (tacitness), firm-specific factors, and stickiness. As a result, external technology cannot be easily transferred and applied to different domains, and often firms fail to successfully create innovation from it (von Hippel 1994; Teece, Pisano, and Shuen 1997).

Furthermore, the costs of the transfer processes may also reduce the efficiency of external technological sourcing (Williamson 1985; Lowe and Taylor 1998). When technology is transferred, there are considerable costs involved, including costs associated with finding relevant technology providers, negotiating with providers, transferring technologies to the firm, and finally transforming them into new innovation.

2.1.2. *Breadth of external technology acquisition*

Considering the different advantages and disadvantages of external technology acquisition, firms need to pay attention to the execution of external technology acquisition. Hence, determining the extent of external technology acquisition becomes the most important issue.

Previous studies on innovation consider breadth as a significant component in measuring the extent of innovation activities to be undertaken (Laursen and Salter 2006; Leiponen and Helfat 2010; Chen, Chen, and Vanhaverbeke 2011). Laursen and Salter (2006) use the concept of breadth in examining the effects of openness of the external search strategy on the innovative performance of firms. Leiponen and Helfat (2010) adapt the concept of breadth in measuring the extent of innovation objectives and external knowledge sources, and investigate its impact on technological innovation. In this paper, we apply the concept of breadth to capture the extent of external technology acquisition and hypothesise that the breadth of external technology acquisition is associated with the technology innovation performance of firms. The breadth of external technology acquisition of a focal firm is defined as the number of different technology providers that the firm utilises for its external technology acquisition.

Technological innovation is created through the connection, integration, and recombination of diverse technologies and knowledge (Galunic and Rodan 1998). Sourcing external knowledge broadly has a significant effect on a firm's innovation performance, because the external knowledge is used to create innovation. There are various types of technology providers such as other firms or research organisations, and each type of technology provider possesses different knowledge and technologies in terms of their characteristics and contents. For example, universities and research institutes have an advantage in basic research and technologies while most firms possess commercially ready technologies (Marques, Caraça, and Diz 2006). Therefore, if a firm adopts external technologies from various types of technology providers, the firm can greatly enrich its internal knowledge and technology base. This large base allows for a recombination of diverse knowledge and leads to innovation (Fleming and Sorenson 2001).

Moreover, to enhance their innovation performance, it is imperative for firms to acquire technical knowledge that is relevant, accurately fits their needs, and can be easily absorbed. When firms utilise external sources, benefits will not be instantaneous as it requires time and extensive effort to understand the norms and routines of different external knowledge channels. Therefore, *ex ante*, it is difficult for managers to recognise which external source will become the most profitable (Laursen and Salter 2006). Under conditions of uncertainty, by accessing more knowledge sources, firms enhance the probability of obtaining valuable knowledge for technological advances (Leiponen and Helfat 2010). The same logic applies to external technology acquisition. *Ex ante*, managers do not know which external technology provider will supply the most beneficial technologies. Under such condition of uncertainty, the likelihood of obtaining relevant and valuable technology through external technology acquisition increases as the number of external technology providers increases. Therefore, by accessing a broader spectrum of external technology providers, firms enhance the possibility of gaining relevant technological knowledge, positively affecting their subsequent innovation outcomes.

Although we assume that the breadth of external technology acquisition is associated with subsequent technological innovation of firms, we also argue that access to a wide variety of external technology providers may negatively affect the firms' subsequent innovation performance. When a firm accesses a wide range of different external technology providers, there may be too many external technologies for a firm to explore and choose between. With too many options, it becomes difficult for firms to select the most relevant and beneficial external technology. A firm's lack of absorptive capacity can also prevent it from successfully incorporating a

large number of external technologies and thus negatively affects firms' subsequent technology innovation (Koput 1997). Accessing a broad variety of external technology providers may also result in an attention allocation problem (Koput 1997). Given the large number of external technologies, only a few of these are given the required level of attention or effort. Considering these potential negative effects, we propose that there is a point at which the breadth of external technology acquisition becomes disadvantageous and propose the following hypothesis:

Hypothesis 1: The breadth of external technology acquisition of a firm has an inverted U-shaped relationship with its subsequent innovation performance.

2.2. *Internal R&D capabilities*

Although in many industries the importance of external technology acquisition for subsequent innovation has been emphasised, internal R&D capabilities are still the most important source of technological advance. The level of R&D activities and internal knowledge base are important components of internal R&D capabilities. Firms have different levels of R&D activities and knowledge (Caloghirou et al. 2004), and these differences may cause varying innovation performances across firms.

2.2.1. *Level of internal R&D activities*

Innovation is a process in which organisations define problems and then actively develop new knowledge to solve these problems (Nonaka 1994). Firms may enhance their understanding of existing knowledge and convert such understanding into new types of knowledge through internal R&D activities. Moreover, internal R&D activities strengthen the interactions among individuals and organisations. Greater commitment to internal R&D leads to a greater rate of new discoveries, as well as to improvements in the flow of new scientific knowledge into firms. Furthermore, because internal knowledge bases are built through long-term R&D investments and learning-by-doing (Lundvall and Nielsen 1999), continuous efforts for internal R&D are required for firms to build up their internal knowledge bases and reinforce long-term innovative capabilities. Therefore, the level of internal R&D activities is significantly associated with the technology innovation performance of firms, leading to the following hypothesis:

Hypothesis 2: The level of internal R&D activities of a firm is positively associated with its subsequent innovation performance.

2.2.2. *Internal knowledge base*

Having a strong knowledge base is the key to successful technological innovation. Innovation is often the result of creating something new and adding value through the recombination and reconfiguration of existing knowledge, know-how, and technologies (Schumpeter 1934; Winter 1987; Kogut and Zander 1992; Grant 1996). The internal knowledge base of a firm is the base for new technological developments; hence, it helps firms to innovate. In addition, the existing knowledge base enhances the abilities of firms to recognise, search, and represent problems, and to assimilate and utilise new knowledge for problem solving (Kim 1999). Furthermore, because recombining internal knowledge does not require the same lengthy assimilation processes or learning periods of external knowledge, large internal knowledge bases allow firms to innovate more rapidly. Overall, a large internal knowledge base will positively affect the firms' subsequent innovation performance, allowing us to build the following hypothesis:

Hypothesis 3: The size of the internal knowledge base of a firm is positively associated with its subsequent innovation performance.

2.3. *Interactions between external technology acquisition and internal R&D*

Although it is theoretically possible for firms to source all of their technology from only external or internal sources, excessive focus on either is likely to lead to inferior outcomes due to the inherent risks, such as obsolescence of internal capabilities or loss of core technological competencies (Teece 1986; Brown and Eisenhardt 1997; Teece et al. 1997). Recent studies on technology acquisition strategy have emphasised the simultaneous use of external sourcing and internal R&D. To generate the important knowledge flow between external sources and internal R&D, it is necessary for firms to pursue both external sourcing and internal R&D simultaneously (Appleyard 1996; Veugelers and Cassiman 1999; Vanhaverbeke, Duysters, and Noorderhavern 2002; Cassiman and Veugelers 2006; Laursen and Salter 2006; Rothaermel and Alexandre 2009).

The impacts of external technology acquisition and internal R&D on the subsequent performance of firms are not independent (Jones, Lanctot, and Teegen 2001). Although one strategy may serve as a substitute for the other, there are ample arguments asserting that external technology acquisition and internal R&D are complementary (Veugelers and Cassiman 1999; Caloghirou et al. 2004; Cassiman and Veugelers 2006; Rothaermel and Alexandre 2009). Arguments on the complementary relationship between external technology acquisition and internal R&D are based on the concept of absorptive capacity (Cohen and Levinthal 1990). Absorptive capacity is the ability to search, scan, and assimilate new knowledge that originates from external sources (e.g. discoveries made in university or government labs or by competitors), and to use this new knowledge for subsequent innovation and commercial activities. Absorptive capacity is strongly linked with internal R&D, such as the level of internal R&D activities and the size of the firm's knowledge base (Cohen and Levinthal 1990; Kim 1999). Therefore, interactions between external technology acquisition and internal R&D may be significantly associated with subsequent technology innovation of firms.

2.3.1. *Interaction between the breadth of external technology acquisition and the firm's level of internal R&D activities*

Internal R&D has two functions: not only does it generate new knowledge, but it also enhances the absorptive capacity of the firm. Absorptive capacity and internal R&D activities are closely linked (Cohen and Levinthal 1990; Murovec and Prodan 2009); hence, internal R&D activities may affect the relationship between external technology acquisition and subsequent innovation performance of firms. When firms utilise external technologies for innovation, there may be gaps between the internal knowledge base and the externally acquired technologies. Through internal R&D activities, firms can fill these gaps and utilise external technologies more efficiently. Empirical tests support the argument that higher levels of R&D activities improve the ability of firms to exploit external knowledge sources (Gambardella 1992; Mowery, Oxley, and Silverman 1996). With more internally available resources, the relationship between external technology acquisition and firm performance becomes stronger (Jones et al. 2001). Therefore, we propose that internal R&D activities may have a complementary relationship with external technology acquisition in creating firms' subsequent innovation. This relationship serves as the base for the following hypothesis:

Hypothesis 4: The interaction of the level of a firm's internal R&D activities and the breadth of its external technology acquisition has a positive effect on the firm's subsequent innovation performance.

2.3.2. *Interaction between the breadth of external technology acquisition and the firm's internal knowledge base*

Firms that possess prior knowledge related to the external knowledge can understand the external knowledge better and readily apply it for innovation purposes (Cohen and Levinthal 1990; Lee, Lee, and Pennings 2001). Firms that have larger internal knowledge bases are more likely to possess prior knowledge that is related to the externally acquired technology; hence, they may have a significant advantage in utilising the externally acquired technology in their subsequent technological innovation.

Moreover, the internal knowledge base and absorptive capacity are closely linked (Cohen and Levinthal 1990). Because internal knowledge bases are built through continuous efforts and learning, firms with larger internal knowledge bases are more likely to possess efficient learning processes and broad experiences. Firms with greater internal knowledge bases can enhance their innovativeness by effectively combining their internal knowledge with externally acquired technology. Therefore, the internal knowledge base of a firm has a complementary relationship with external technology acquisition in shaping subsequent innovation. (Jones et al. 2001). Accordingly, the hypothesis can be stated as:

> Hypothesis 5: The interaction of the size of a firm's internal knowledge base and the breadth of its external technology acquisition has a positive effect on the firm's subsequent innovation performance.

3. Research methods

3.1. *Data and sample*

In the empirical part of this study, we combine data from two different sources. The first is a survey, conducted by a Korean research institute, listing the overall knowledge creation and management activities of South Korean firms in the 2005–2007 time period. The survey database contains not only abundant information related to technology innovation, such as external technology acquisition, patenting activities, and R&D spending, but also general information, such as sales and the number of employees. The firms in the data-set are Korean firms which actively generated intellectual property. Specifically, the research institute identified 11,292 firms which had at least applied for one patent each in 2005 and 2006. Out of these firms, 3169 were randomly selected to participate in the survey. A total of 1350 questionnaires were successfully retrieved, yielding a response rate of 42.6%. The survey respondents were mostly managers of corporate intellectual property management departments or technology transfer centres. In this study, we employ a subset of the available data, which includes only the data from the 1152 firms that provided information on all the variables considered in our analysis.

The second data source includes information on each firm's number of Korean patent applications from 2008 to 2010. The data are obtained from the Korea Intellectual Property Rights Information Service database.

The survey providing the data used in our analysis was conducted in 2008, and substantial time has passed since the survey was carried out. While performing an analysis with outdated data limits the implications of the research, we are convinced that in our case, the advantages outweigh the disadvantages. While firm survey data have the advantage of obtaining extensive firm data, many surveys such as the Community Innovation Survey redact the names of the firms. Thus, researchers are not able to complement and cross-check the data-set with data from other sources, leading to potential statistical problems such as respondent bias and simultaneity issues. After signing a non-disclosure agreement, we were given access to the full data-set including the names of the participating firms. However, this special access was limited to the results of the 2008 survey. Due to the identification of the firms, we were able to supplement our survey data

with a time-lagged dependent variable from another database, thus allowing us to eliminate potential respondent bias and simultaneity issue and improve the reliability of the analysis. Moreover, the linkage of the data from different sources allowed us to increase the time frame of data collection and investigate time-lagged effects.

3.2. *Dependent variable*

This paper examines the effects of external technology acquisition, internal R&D activities, and their interactions on the subsequent innovation performance of firms. The methodology used is based on prior research measuring the innovation performance based on the number of patents (Hagedoorn and Schakenraad 1994; Henderson and Cockburn 1994; Ahuja 2000; Stuart 2000; Owen-Smith and Powell 2004; Rothaermel and Hess 2007; Rothaermel and Thursby 2007; Rothaermel and Alexandre 2009). Patent count is not only a typical method for measuring technological innovation but is also highly correlated with other indicators of firm innovativeness, such as the number of new product introductions (Hagedoorn and Cloodt 2003). In particular, we measure the technology innovation performance of firms by the number of Korean patents applied for from 2008 to 2010. The 1152 firms in our sample applied for a total of 6186 patents, an average of 5.37 patents per firm.

3.3. *Independent variables*

The survey we employed classified external technology providers into seven types: subsidiaries, domestic customer or supplier firms, domestic other firms, domestic universities, domestic research organisations, overseas firms, and overseas research organisations. However, because the motivation behind these classification criteria remains unclear, we re-classified the types of technology providers as follows:

First of all, in a strict sense, it is hard to say that technology acquisition from subsidiaries is an example of external technology acquisition. The technological and organisational boundaries of a parent company and its subsidiaries are ambiguous. A parent firm could explore the technologies of its subsidiaries effortlessly, and transferring the technology is easy compared to the transfer from external technology providers. Also, there are a variety of cases in which just the ownership of co-developed technologies is transferred from the subsidiary to the parent firm. Therefore, we exclude all cases classified as transfers from subsidiaries from our data-set.

Second, we re-categorised the remaining six types of technology providers according to whether they are domestic or foreign and whether they are firms or research organisations. This leads to the external technology providers being categorised into domestic firms, domestic research organisations, foreign firms, and foreign research organisations.

Previous literature distinguishes domestic technology acquisition from foreign technology acquisition (Basant and Fikkert 1996; Hu, Jefferson, and Jinchang 2005). In domestic technology acquisition, more frequent contact with the technology providers helps to increase the success rate of the technology transfer. Foreign technology acquisition is difficult in terms of implementation, but allows the firms to access more diverse technology alternatives and provides foreign cutting-edge technologies. Therefore, whether the technology provider is domestic or foreign is an important criterion to classify the type of technology provider.

Whether the technology provider is a research organisation or a firm is another important criterion for classifying the type of technology provider. Technology acquisition from a research organisation or from a firm is different in terms of many aspects such as the purpose of sourcing and type of technologies provided.

Research organisations such as research institutes and universities allow easy access to basic technologies and scientific knowledge (Marques et al. 2006). Firms in knowledge-intensive technology sectors, which are eager to acquire new technologies, were found to more frequently build partnerships with research organisations (Hanel and St-Pierre 2006). While research organisations are eager to commercialise their technologies, they are usually lacking the knowledge and capabilities to do so (Dorf and Worthington 1990; Lee and Win 2004). Therefore, most research organisations are open to collaboration with firms and support amicable transfers of their technology.

Meanwhile, a firm could also decide to obtain commercially ready technologies from firms in the same industry such as its customers, suppliers, and even rivals, because the technologies offered by research organisations often have a relatively low practicality compared to those of firms (Dorf and Worthington 1990). Therefore, whether the technology provider is a research organisation or a firm is another important criterion for classifying the type of technology provider.

To construct a variable indicating the breadth of external technology acquisition (BREADTH), we utilise binary values for the four technology providers listed in Table 1, where '0' indicates nonuse of the given type of technology provider and '1' indicates the use of the given type of technology provider. Subsequently, we sum up the codes for each firm, so that a firm using no external technology provider gets a score of zero whereas a firm sourcing its technology from all the different types of technology providers gets a score of four. In other words, firms who score higher in terms of utilising technology providers have a broader range of external technological acquisition than firms with lower scores. Other researchers such as Laursen and Salter (2006) and Leiponen and Helfat (2010) have adopted a very similar approach to measure breadth.

Traditionally, the level of internal R&D activities is measured by R&D intensity, which is calculated by dividing R&D expenditure over sales. R&D intensity represents not only the internal R&D activities of firms but also serves as an indicator of their absorptive capacity (Cohen and Levinthal 1990). However, empirical studies have demonstrated that there is no evidence of a positive relationship between R&D intensity and innovation (Stock, Greis, and Fischer 2001; Kang and Kang 2009). Stock et al. (2001)'s study on computer modem manufacturers empirically proves that there is an inverted U-shaped relationship between R&D intensity and product performance. This implies that there is a diminishing return to internal R&D activities. Under conditions of limited resources and capabilities, increasing R&D intensity may cause attention allocation problems. A firm is a complex system composed not only of R&D but also of many other activities. When a firm excessively concentrates its resources and capabilities on its R&D activities, other critical activities may be neglected. Besides, excessive R&D investment may reduce the efficiency of R&D spending. Thus, firms may experience a diminishing return to the level of internal R&D activities. Taking into consideration this diminishing return, we employ a logarithmic transformation of R&D intensity (LOGRDINT) as an alternative measure of the level of internal R&D activities.

Table 1: Technology providers used by South Korean firms in 2005–2007 ($n = 1152$).

Type of technology provider		No. of firms that used each type of tech. provider	Percentages of firms that used each type of tech. provider
Domestic	Firms	222	19.3
	Research institutes	306	26.6
Overseas	Firms	125	10.9
	Research institutes	38	3.3

A firm's internal knowledge base (KNOWBASE) is measured by the number of Korean patents that each firm had held in 2007. By definition, a patent represents a unique and novel element of knowledge possessed by an individual or an organisation. Therefore, a set of patents represents a collection of distinct units of knowledge and is naturally an element of a firm's knowledge base (Jaffe, Trajtenberg, and Henderson 1993; Ahuja and Katila 2001). The number of patents held by a firm can represent its technological knowledge accumulated from previous R&D and other innovative activities. Therefore, the number of patents is a useful tool for measuring the internal knowledge base of a firm.

3.4. *Control variables*

In this study, we employ several control variables, such as firm size, start-ups, market size, and dummy industry variables. Firm size has an important effect on the innovativeness of firms; hence, it has been used as a control variable in many innovation studies. In this study, firm size is measured by the logarithm of the number of employees of the sample firms. Meanwhile, start-up firms are likely to innovate more vigorously than incumbents; hence, we control for whether the firms are recent start-ups (STARTUP). Firms whose operations commenced in 2001–2005 are considered start-ups. A dummy variable is used and is assigned the value of '1' if the sample firm is a start-up and '0' if otherwise.

In addition, we control for the effect of a sample firm's market size (GEOMARKET). Firms operating in international markets are more likely to face competition than those only operating in the domestic market and will strive to innovate more intensively. In this research, a value of '0' is assigned to the GEOMARKET variable if the sample firm operates only domestically and '1' if the sample firm operates internationally.

This paper uses the number of Korean patent applications from 2008 to 2010 to measure the firms' innovation performance. However, the commercial importance of patents varies among industries and technologies, and thus firms may display systematic differences in their propensity to use patents to protect important technological advances (Mowery et al. 1996). Therefore, we include six industry dummy variables: machinery, chemicals, electronics, construction, business services, and others, to control for the effects of differences among industries.

3.5. *Empirical estimation method*

In this study, we use the number of patent applications from 2008 to 2010 to measure the firms' innovation performance. The number of patent applications is a countable integer value. When analysing such a variable, researchers can use either the Poisson regression model or the negative binomial regression model in their empirical analysis. The variance of our dependent variable is larger than its mean; hence, our dependent variable shows an over-dispersion and violates the basic conditions of the Poisson distribution (see Table 2). Thus, we choose to employ the negative binomial regression model which is suitable for a dependent variable that shows over-dispersion.

4. Results

Table 1 lists the four types of external technology providers considered in our analysis and shows the number of sample firms which acquired technologies from each of the different providers. The results indicate that domestic research organisations were the most often used source of technologies, followed by domestic firms. This corresponds with the industrial characteristic of South Korea where the collaborations between firms and research institutions such as universities and

research centres is strong due to efficient government support. Universities and research centres actively transfer their technologies to firms, and firms utilise these technologies to enhance their innovation and develop new products.

Table 2 presents a summary of the descriptive statistics and correlations among our variables. The table shows the relatively low correlations between the variables; hence there is no evidence of multicollinearity. Table 3 shows the results of the three negative binomial regression models explaining the firms' subsequent innovation performance. All three models contain our control variables such as LOGSIZE, STARTUP, GEOMARKET, and industry dummy variables. Model 1 contains only the control variables. Model 2 includes the three independent variables BREADTH, LOGRDINT, and KNOWLEDGEBASE to analyse the effects of the breadth of external technology acquisition, size of the internal knowledge base, and internal R&D activities on the subsequent innovation performance of the firms. Model 3 adds the squared value of BREADTH to examine a possible inverted U-shaped relationship between the breadth of external technology acquisition and subsequent technology innovation performance. Model 3 also contains two interaction variables to test Hypotheses 4 and 5. To examine our Hypothesis 5, which states that the level of internal R&D activities is complementary to the breadth of external technology acquisition in shaping subsequent technological innovation, we use an interaction term of BREADTH and LOGRDINT. In addition, to examine Hypothesis 4, which suggests that there is a complementary relationship between the breadth of external technology acquisition and the firm's internal knowledge base, we employ an interaction term of BREADTH and KNOWBASE. All three estimations are reliable and interpretable; the chi-square values are significant at the $p < .01$ level.

We find strong support for our Hypothesis 1, which predicts that the breadth of external technology acquisition has an inverted U-shaped relationship with the firms' subsequent innovation performance. First, the parameter for BREADTH (representing the breadth of external technology acquisition) in Model 3 is positive and significant at the $p < .05$ level, showing that the breadth of external technology acquisition is an important factor in explaining innovation performance. Second, the parameter for BREADTH squared is negative and significant, showing that when firms use various types of technology providers in their technology acquisition, they experience decreasing returns. Results show that the point where breadth appears to have negative consequences for innovation performance, that is, the 'tipping point', is between one and two technology providers, so that if firms use more than two types of technology providers for technology acquisition, negative returns follow. Therefore, firms must utilise an adequate number of channels for external technology acquisition.

Table 2: Descriptive statistics and correlations ($n = 1152$).

	Mean	SD	1	2	3	4	5	6	7
Technology innovation	14.53	71.84							
1. BREADTH	0.60	0.87	1.00						
2. KNOWBASE	32.97	277.74	0.11	1.00					
3. LOGRDINT	1.53	1.44	−0.08	−0.06	1.00				
4. BREADTH × KNOWBASE	46.09	1045.09	0.14	0.94	−0.04	1.00			
5. BREADTH × LOGRDINT	0.82	2.05	0.49	−0.02	0.45	−0.01	1.00		
6. LOGSIZE	3.97	1.50	0.13	0.19	−0.46	0.10	−0.18	1.00	
7. STARTUP	0.14	0.35	−0.04	−0.03	0.21	−0.01	0.05	−0.27	1.00
8. GEOMARKET	0.57	0.50	0.09	0.06	−0.10	0.03	−0.02	0.31	−0.08

Table 3: Negative binomial regression, explaining independent variables and subsequent innovation performance ($n = 1152$).

	Model					
	I		II		III	
	Dep. variable					
	Innovation Performance		Innovation Performance		Innovation Performance	
Indep. variables	Coefficient	SE	Coefficient	SE	Coefficient	SE
BREADTH			−0.022	0.047	0.231**	0.117
BREADTH^2					−0.082**	0.038
KNOWBASE			0.002***	0.001	0.006***	0.001
LOGRDINT			0.138***	0.032	0.117***	0.036
BREADTH × KNOWBASE					−0.002***	0.000
BREADTH × LOGRDINT					0.006	0.030
LOGSIZE	0.672***	0.027	0.649***	0.033	0.595***	0.034
STARTUP	0.234	0.122	0.179	0.119	0.166	0.117
GEOMARKET	0.051	0.092	0.030	0.090	0.0047	0.088
Industry dummies	Yes		Yes		Yes	
No. of observations	1152		1152		1152	
Log likelihood	−3414.96		−3388.45		−3367.56	
Pseudo R^2	0.0974		0.1044		0.1099	
Chi-square	737.03***		789.95***		831.74***	

*$p < .10$.
**$p < .05$.
***$p < .01$.

Models 2 and 3 show that the parameter for KNOWBASE is positive and significant at the $p < .01$ level. This result supports Hypothesis 2, which states that firms with a larger internal knowledge base are more likely to have better subsequent innovation performances. A firm's internal knowledge base can be seen as a set of raw materials required to create subsequent technological innovation. Our finding corresponds with our previous statement that firms innovate by recombining existing knowledge and resources rather than by creating something from nothing.

In Models 2 and 3, the parameter for LOGRDINT is positive and significant at the $p < .01$ level. Therefore, Hypothesis 3, asserting that the firms' level of internal R&D activities is positively associated with their subsequent innovation performance, is supported.

We find no evidence supporting Hypothesis 4, which states that the level of internal R&D activities of a firm is complementary to the breadth of its external technology acquisition in shaping technological innovation. Model 3 shows that the parameter for the interaction term between the breadth of external technology acquisition (BREADTH) and the level of internal R&D activities (LOGRDINT) is not significant. Thus, there is no empirical evidence for a complementary relationship between external technology acquisition and internal R&D activities.

Our results also do not support Hypothesis 5, which suggests that the internal knowledge base of a firm is complementary to the breadth of its external technology acquisition in shaping the subsequent innovation performance. Model 3 shows that the interaction effect between internal knowledge base (KNOWBASE) and the breadth of external technology acquisition (BREADTH) is significant at the $p < .01$ level. However, it has a negative sign, indicating a substitutive relationship between the size of the internal knowledge base and the breadth of external technology acquisition in shaping subsequent technological performance. This result is in contrast

to prior assertions on the complementary relationship between external sourcing and internal R&D capabilities.

5. Discussion

In this study, we investigate the effects of the breadth of external technology acquisition and the two components of internal R&D capabilities – the level of internal R&D activities and the internal knowledge base – on the subsequent technological innovation performance of firms. Furthermore, we examine the effects of interactions between external technology acquisition and the two components of internal R&D capabilities to prove whether external technology acquisition is complementary to internal R&D or not. The results point to several important findings.

Our results show that there is a point at which the breadth of external technology acquisition becomes disadvantageous in terms of technological competences. Appropriate external technology acquisition has significant advantages in shaping new technology innovation. However, heavy reliance on external technology acquisition generates negative consequences on the technological competence of firms, ultimately weakening their competitive advantage (Miles and Snow 1992; Sen and Rubenstein 1989; Quinn 1992; Dodgson 1993). Therefore, firms must keep the breadth of external technology acquisition at the optimal level to maximise the benefits derived from external technology acquisition. However, *ex ante*, it is impossible for managers to recognise which breadth of external technology acquisition is most beneficial for their firms. As such, managers determine the optimal breadth of their external technology acquisition through trial and error. Given that trial and error may result in a waste of resources and capabilities, managers should make efforts to find the optimal level of external technology acquisition as fast as possible.

The study confirms that the level of internal R&D activities and the size of the firm's internal knowledge base are positively associated with subsequent innovation performance whereas external technology acquisition has a curvilinear relationship with the subsequent innovation performance. Although, under conditions of accelerating technological change, the importance of external knowledge in improving the innovative performance has been emphasised, the internal knowledge base of a firm is still the basis of its technological innovativeness. Moreover, internal R&D allows firms to gain a deeper understanding of existing internal and external knowledge, and thus helps them create new technological advances. Therefore, firms need to make great efforts towards internal R&D and to enhance their internal knowledge base to maintain technological competence and enjoy long-term competitive advantage.

We find no evidence supporting the complementary relationship between the external technology acquisition and internal R&D activities. One likely interpretation of this finding could be the inherent trade-off between external technology acquisition and internal R&D activities in terms of resource allocation. Available resources for technological renewal are limited; hence, the more resources firms invest on external technological acquisition, the less they invest in internal R&D. The results imply that the inherent substitutability between external technology acquisition and internal R&D may offset the complementarity between the two.

Our results show that the internal knowledge base of a firm is substitutive for its external technology acquisition in shaping subsequent technological innovation. One likely interpretation of this finding is that it is caused by the NIH syndrome (Katz and Allen 1982). The internal knowledge base of a firm helps to improve the effect of external technology acquisition, but only if the firm can overcome the NIH syndrome (Harrigan 1986; Cohen and Levinthal 1989). Because a firm that possesses a large internal knowledge base is more likely to mistakenly believe that it monopolises valuable knowledge in its field, the firm is more likely to suffer internal resistance to externally acquired knowledge. The resistance may hinder innovative activities of the firm and

adversely affect its technological performance. Another likely interpretation of this finding is the path-dependency of firms. Because firms with a strong internal knowledge base tend to have established firm-specific technological trajectories, they are more likely to exhibit path-dependent search behaviour. Therefore, a large internal knowledge base of a firm may decrease its receptivity to externally acquired knowledge (Kim and Song 2007).

It is inevitable for firms to use external technology acquisition. More and more innovation-active organisations try to leverage both external sourcing and internal R&D to enhance their innovative capabilities (Chesbrough 2003; Laursen and Salter 2006). However, the study finds that excessive external technology acquisition generates negative consequences on subsequent innovation performance and external technology acquisition may be not complementary to internal R&D in terms of technological competence. The findings clearly show that external technology acquisition can be a double-edged sword for firms' technological competences and long-term competitive advantage. It is difficult for firms to successfully leverage both external sourcing and internal R&D. Therefore, firms should maintain harmony and strike a balance between their external sourcing and internal R&D for technological renewal and long-term competitive advantage.

Additionally, the study examined the impact of independent variables on the firms' financial performance such as sales growth, return on investment, and operating growth rate from 2008 to 2010. However, we could not find any significant relationship between our independent variables and the firms' financial performance. One likely interpretation of this finding is that the financial performance of firms deteriorated due to the global recession in the second half of 2008. The effect of global recession may hinder the impact of external technology acquisition and internal R&D on financial performance.

6. Limitations and future research

This study only investigates the role of external technology acquisition and internal R&D in terms of new technology development. To gain further insights into the effects of external technology acquisition, internal R&D, and their interactions on innovation, future research must examine the effects of our innovation determinants on other measures of firm performance such as new product introductions or process enhancements.

This study focusses on measuring the breadth of external technology acquisition; but did not analyse the effects of each different type of technology provider on the innovation of firms. Although there are not many studies on the impact of the type of technology provider in external technology acquisition, there are ample studies that explore effects of partner types in R&D cooperation (Belderbos, Carree, and Lokshin 2004; Fritsch and Franke 2004; Arranz and de Arroyabe 2008; Aschhoff and Schmidt 2008; Kang and Kang 2010). Most of these studies find that the relationship between R&D cooperation and innovative performance varies depending on the type of partner. Thus, it can be inferred that the effect of external technology acquisition also varies depending on the type of technology provider. Therefore, a new research challenge is to analyse and compare the effects of each individual technology provider on technological innovation and other measures of innovation performance.

Previous literature has suggested depth and breadth as two important dimensions of external technology acquisition, and a variety of studies examine both depth and breadth simultaneously (Laursen and Salter 2006; Chiang and Hung 2010). However, due to the limitation of the available data, our research could not analyse the effect of the depth of external technology acquisition. The survey data we employed only showed whether a firm adopted external technologies from each type of external technology provider or not. Consequently, this only allowed us to measure the breadth of external technology acquisition, but not the depth. Further research

that examines the effect of both breadth and depth at the same time could draw a more significant conclusion.

Before performing our empirical analysis, we expected complementary relationships between external technology acquisition and the two components of internal R&D capabilities. However, we found no empirical evidence for such complementary relationships. In fact, it is still unclear whether external sourcing and internal R&D are complements or substitutes. A range of studies finds that external sourcing and internal R&D are complementary in shaping innovative performance (Caloghirou et al. 2004; Cassiman and Veugelers 2006; Lokshin, Belderbos, and Carree 2008; Schmiedeberg 2008; Tsai and Wang 2008; Rothaermel and Alexandre 2009), whereas a diverse set of empirical work finds a substitutive relationship between external and internal sources of innovation (Blonigen and Taylor 2000; Higgins and Rodriguez 2006; Laursen and Salter 2006; Haro-Dominguez, Arias-Aranda, Llorens-Montes, and Moreno 2007; Watkins and Paff 2009). The relationship between external sourcing and internal R&D can vary depending on country-specific contexts, industries, external sourcing modes, or firm-specific conditions (Jiang, Wu, and Zhu 2012). Additional analyses examining conditions under which external sourcing and internal R&D become complementary are recommended.

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