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Abstract

Recent research identify the type of partner as a critical factor determining the effect of R&D collaboration on innovation. Most firms tend to utilize various types of R&D collaboration partners simultaneously, and partnerships between different types of partners show different properties. Thus, the effect of R&D collaboration may vary depending on partner types. This study considers four partner types: competitors, customers, suppliers, and universities. It empirically examines the effect of R&D collaboration with each type of partner on product innovation, employing the Korea Innovation Survey data. Results show that R&D collaborations with customers and universities have a positive effect on product innovation, whereas R&D collaborations with suppliers and competitors have an inverted-U shape relationship with product innovation.

Keywords: R&D collaboration, product innovation, competitors, customers, suppliers, universities

1. Introduction

Since market and technology are changing rapidly, firms cannot successfully achieve product innovation by only using internal resources and capabilities. External sourcing of resources and capabilities for accelerating product innovation are becoming more and more important in accelerating firms' product innovation (Chesbrough, 2003; Hagedoorn and Duysters, 2002; Keil, 2002; Leonard-barton, 1995); particularly, the R&D collaboration that allows firms to combine internal and external resources and capabilities occupies a crucial position in innovation strategies (Bailey et al., 1998; Miotti and Sachwald, 2003). Firms vigorously use R&D collaboration for innovation, and the frequency of R&D collaboration has rapidly increased for the last two decades (Hagedoorn, 2002; Hagedoorn and van Kranenburg, 2003; Tyler and Steensma, 1995).

With the increasing importance of R&D collaboration in innovation, many research have intensively explored factors affecting the success of R&D collaboration (Kleinknecht and Reijnen, 1992; Fritsch and Lukas, 2001; Tether, 2002; Belderbos et al., 2004b). In particular, recent research identify the type of R&D collaboration partner as a critical factor determining the effect of R&D collaboration on innovation (Tether, 2002; Fritsch and Lukas, 2001; Belderbos et al. 2004b; Fritsch and Franke, 2004; Lhuillery and Pfister, 2009). Most firms simultaneously collaborate with various partner types, such as competitors, customers, suppliers, universities, and others. Each type of partner has different resources and capabilities and exhibits different kinds of behavior in R&D partnership. These differences affect the profitability and the efficiency of R&D collaboration; thus the effect of R&D collaboration on product innovation varies depending on partner types.

However, previous studies that analyze the effects of R&D collaborations with various partner types on innovation have shown confusing and chaotic results (Belderbos et al. 2004b; Fritsch and Franke, 2004; Lhuillery and Pfister, 2009). For example, Belderbos et al. (2004b) show that R&D collaboration with competitors has a positive effect on product innovation, whereas Aschhoff and Schmidt (2008) find no positive effect. Therefore, additional analysis is required to resolve the confusing and chaotic results and to broaden the understanding on this research topic.

This study focuses on the different effects of R&D collaboration with various partner types on product innovation. We consider four major types of R&D collaboration partners: competitors, suppliers, customers, and universities. We intensively analyze different properties of R&D partnership with each partner type, and

establish four hypotheses that illustrate the effects of R&D collaborations with each type of partner on product innovation. We examine these four hypotheses by simultaneously incorporating variables that measure the degree of utilizing R&D collaboration with each type of partner within a single empirical model. The effects of four types of R&D collaboration partners are analyzed by employing the negative binomial regression model. We utilize the 'Korea Innovation Survey 2005: manufacturing sector (KIS 2005)' dataset covering the degree of R&D collaboration with 1) competitors, 2) suppliers, 3) customers, and 4) universities.

The contribution of this study to the research of R&D collaboration is threefold. First, the results reinforce previous research which asserts that firms should consider what type of partner they select for R&D collaboration. Second, the result highlights the relative efficiency of collaboration with different types of partners for product innovation. It grants strategic implication in determining the priority among types of R&D collaboration partners. Third, this research provides an explanation that partially resolves and integrates the conflicting results of previous research on the relationship between R&D collaboration and innovation.

2. Theoretical backgrounds and hypotheses

2.1. R&D collaboration and innovation

A major question in R&D collaboration research is whether or not R&D collaboration has a positive effect on firms' innovation (Belderbos et al., 2004b). Previous research suggest that R&D collaboration enhances firms' innovation because of its various merits, such as sharing costs and risks of technological development (Das and Teng, 2000; Tyler and Steensma, 1995), reducing the term of innovation projects (Pisano, 1990), providing a window for monitoring technological advance and allowing rapid access to new technology (Hamel, 1991; Roberts and Berry, 1985; Dodgson, 1993), diversifying firms' technological competence (Kogut, 1988; Das and Teng, 2000), granting advantages of scope and scale of economies (Kogut, 1988; Das and Teng, 2000), and overcoming entry barriers (Hagedoorn, 1993).

However, empirical research on the relationship between R&D collaboration and innovation suggest conflicting and confusing results. Some find a positive relationship (Klomp and van Leeuwen, 2001; Janz et al., 2003; van Leeuwen, 2002; Lööf and Heshmati, 2002; Criscuolo and Haskel, 2003; Faems et al., 2004; Aschhoff &

Schmidt, 2008; Belderbos et al., 2004b; Cincera et al., 2003; Teng, 2006), while others prove a negative relationship (Dyer et al., 2006; Janz et al., 2003; Okamuro, 2007; Teng, 2006;). Such conflicting results imply that R&D collaboration does not always have a positive effect on innovation, and that there are more complex factors which determine the effect of R&D collaboration on innovation.

Research on R&D collaboration have intensively explored the factors affecting R&D collaboration performance (Bailey et al. 1998; Belderbos et al., 2004b; Bruce et al. 1995; Doz, 1988; Forrest and Martin, 1992; Fritsch and Lukas, 2001; Hakanson, 1993; Hakanson and Lorange, 1991; Kleinknecht and Reijnen, 1992; Lhuillery and Pfister, 2009; Miotti and Sachwald, 2003; Tether, 2002). A major contribution of recent research was identifying the types of R&D collaboration partners as a major factor determining the relationship between R&D collaboration and innovation (Belderbos et al. 2004b; Fritsch and Lukas, 2001; Fritsch and Franke, 2004; Lhuillery and Pfister, 2009; Tether, 2002). Most firms utilize various types of R&D collaboration partners, such as competitors, customers, suppliers, and universities, simultaneously. Each type of partner possesses different resources and capabilities, and exhibits a different behavior in R&D collaboration relationship. These differences affect the profitability and the efficiency of R&D collaboration. Therefore, the effect of R&D collaboration on innovation varies depending on the partner type.

Many empirical analyses find different effects of various partner types on product innovation. Fritsch and Franke (2004) identify five types of R&D collaboration partners: customers, suppliers, business service firms, competitors, and public research centers. Their research finds that each type of partner differently affects German manufacturing firms' innovation. It empirically proves that customer collaboration has a negative effect, while collaboration with competitors and public research institutes has a positive effect; collaborations with other types of partners show no significant effect on innovation. Belderbos et al. (2004b) consider four partner types – competitors, customers, suppliers, and universities – and find evidence that competitor collaboration and university collaboration have positive effects on product innovation, while collaborations with customers and suppliers show no significant effect. Lhuillery and Pfister (2009) consider three types of R&D partners, competitors, public research institutes, and vertical partners, and find that collaborations with competitors and public research institutes are more likely to generate delay and failure of R&D projects than collaboration with vertical partners. In the case of German firms, Aschhoff and Schmidt (2008) conclude that R&D collaborations with universities positively influence the product innovation, while other types of partners have no significant effect.

<Insert table 1 here>

The effect of each type of partner on product innovation also varies across studies (see Table 1). These confusing results imply that previous studies do not precisely analyze the properties of R&D collaboration with each type of R&D partner. Therefore, further research into the different effects of the various types of R&D collaboration partners on product innovation is strongly required. This study considers four types of R&D collaboration partners: competitors, customers, suppliers, and universities. We intensively investigate the properties of R&D collaborations with each type of R&D partner and empirically analyze the effects of the four types of R&D collaboration partners on product innovation.

2.2. R&D collaboration with competitors

Hakanson and Lorange (1991) assert that whether the partner is a rival or not is a crucial factor affecting R&D collaboration performance in their research on R&D co-operative ventures in the Scandinavia peninsula. A firm and its rivals typically have similar needs in product and process development, so that the knowledge bases of rival firms may be applicable for the firm. Therefore, R&D collaboration with competitors can greatly improve a firm's knowledge base (Lhuillery and Pfister, 2009) and also enhance innovation and firm performance (Belderboset al., 2004b; Lööf and Heshmati, 2002; Aschhoff and Schmidt, 2008). Also, firms can share the risk and cost of large-scaled R&D projects (Miotti and Sachwald, 2003). Belderbos et al. (2004b) find that collaborations with rivals improve firms' productivity. Because improvement of efficiency of production helps firms acquire financial and organizational slacks for technological development, it contributes to firms' product innovation.

However, because a firm and its competitors still remain rivals in the market even as they collaborate for R&D, it is not certain that they will be very collaborative in sharing their knowledge (Miotti and Sachwald, 2003; Lhuillery and Pfister, 2009). Theoretical and empirical results confirm that firms try to acquire some of their partner's knowledge while simultaneously restricting knowledge leakages towards the partner. This asymmetric knowledge sharing could imperil the viability or the success of the partnership (Hamel, 1991; Kesteloot and Veugelers, 1995; Caloghirou et al., 2003; Oxley and Sampson, 2004; Atallah, 2005) and tends to occur more frequently in R&D collaboration between competitors. Competitors have stronger motive of opportunistic

behaviors, such as change of the objective of R&D collaboration and illegal transfer of core technology than other types of partners (Dodgson, 1993; Bruce et al. 1995; Pisano, 1990; Kang and Kang, 2009). Therefore, partners who compete with each other in the market show very uncertain behaviors, which can generate delay and failure in R&D projects. Thus it is possible that R&D collaboration between competitors negatively influence firms' technology innovation. Lhuillery and Pfister (2009) empirically show that collaborations with competitors are more likely to cause delays and failures in innovation than collaborations with suppliers and customers.

Moreover, R&D collaboration with competitors is very difficult to manage (Röller et al., 1997). The generally low proportion of firms collaborating with competitors (compared to the proportion of firms collaborating with other types of partners) is indicative of the difficulties in managing partnerships with competitors (Röller et al., 1997). To maintain this kind of R&D collaboration, firms should build an appropriate but costly cooperation framework and monitoring systems to reduce risks from collaboration (Geringer and Hebert, 1989); however, setting up such safety measures can also increase the rigidity of the collaboration and decrease its efficiency, thus hindering the innovation process (Lhuillery and Pfister, 2009). Moreover, designing such a framework and system may require some specific alliance experience (Lhuillery and Pfister, 2009).

It is possible that R&D collaboration with competitors can positively influence product innovation, but too strong dependency on R&D collaboration with competitors can also negatively affect product innovation. Therefore, we suggest a hypothesis illustrating the relationship between R&D collaboration with competitors and product innovation as follows.

H1. R&D collaboration with competitors has inverted-U shape relationship with product innovation performance

2.3. R&D collaboration with customers

Customers are a major type of R&D collaboration partners. For example, 60 percent of German entrepreneurial firms maintain a collaborative relationship with customers (Fritsch & Franke, 2004). Relatedness of customers to innovation significantly affects innovation performance (Kang & Kang, 2009; Laursen & Salter, 2006; Rothwell et al., 1974; von Hippel, 1988) and knowledge creation (Weck, 2006).

R&D collaboration with customers especially influences product innovation

(Aschhoff & Schmidt, 2008; Tether, 2002). Because customers know their own wants and needs, they can provide firms with the appropriate information for product innovation (Tether, 2002). Customers freely provide complementary knowledge, such as feedbacks of products, and support firms by informing them of the problems in the products that firms have overlooked (Kang and Kang, 2009). Also, R&D collaboration with customers helps reduce the risk of market introduction of innovative product (von Hippel, 1988). Information obtained from customers contributes to the sales growth of innovative product (Belderbos et al., 2004b). It also helps diffusion of innovative product and contributes to success of product innovation (Belderbos et al, 2006), especially in the case of introducing a very new or complex product (Tether, 2002). When firms create better products through innovation, customers are the recipients of the new products (Tether, 2002). Therefore, customers show amicable attitude to R&D collaboration and partner's product innovation, and such attitude is helpful for efficient collaboration process. Based on the various advantage of R&D collaboration with customers on product innovation, we suggest second hypothesis as follows

H2. R&D collaboration with customers positively influences firms' product innovation performance.

2.4. R&D collaboration with suppliers

Suppliers are another major type of R&D collaboration partners. R&D collaboration with suppliers improves the efficiency of firms' product development. R&D collaboration with suppliers reduces unnecessary rework (Loch & Terwiesch, 1998), enables firms to efficiently set up the schedule of product development (Tannenbaum et al., 1992), supports the integration of operation process between firms and suppliers through knowledge sharing (Barratt, 2002), and allows firms to solve technological problems quickly in the process of product development (Katz, 1982). Many research also assert that supplier involvement on product development shortens the time to market, enhances quality, reduces costs, and increases the firm's ability to achieve R&D projects (Birou & Fawcett, 1994; Bonaccorsi & Lipparini, 1994; Clark, 1989; Handfield, Ragatz, Petersen, & Monczka, 1999; Ragatz, Handfield, & Scannell, 1997; Wynstra, van Weele, & Weggemann, 2001).

Since suppliers who provide product components are strongly related with its buyer firms on the same value chain, firms and its suppliers have strongly connected needs of product innovation. Firms and its suppliers should know and understand each

other to intimately integrate product and its components for successful product innovation. R&D collaboration can aid a firm and its partner to understand more about each other. When a firm grows though continuous innovation, the sales of its suppliers also expand. Therefore, suppliers show a positive attitude in the collaboration with their buyer firm for product innovation (Littler et al., 1998; Tjosvold, 1984; Hoegl and Wagner, 2005), and thus the firm and its suppliers exchange their information smoothly (Ancona & Caldwell, 1990; Brown & Eisenhardt, 1995; Littler et al., 1998; Ragatz et al., 1997; Ragatz, Handfield, & Petersen, 2002; Takeishi, 2001).

In addition, R&D collaboration with suppliers enhances the efficiency of production. Collaborations with suppliers reinforce firms' supply chain that is comprised of procurement, production, and distribution (Ellinger, 2002; Fawcett and Magnan, 2002). Belderbos et al. (2004b) empirically show that R&D collaboration with suppliers enhances firms' productivity. Because improvement of efficiency helps firms acquire financial and organizational slacks for technological development, R&D collaboration with suppliers contributes to firms' product innovation. Based on the discussion above, we propose a hypothesis as follows.

H3. R&D collaboration with suppliers positively affects firms' product innovation

2.5. R&D collaboration with universities

As knowledge becomes more and more an important, crucial and necessary part of innovation, universities that produce and spread scientific and technological knowledge play a much more important role in industrial innovation (Marques et al, 2006). The most important advantage from R&D collaboration with universities is that it allows firms to access the results of research in universities that is on the cutting edge of contemporary knowledge and technology (Marques et al, 2006). Firms approach universities for the purpose of exploring knowledge and expertise (Hanel & St-Pierre, 2006), and firms in knowledge based technology sectors that show a strong desire for new technology build partnerships with universities more frequently (Hanel & St-Pierre, 2006). Firms can innovate by utilizing the scientific and technological knowledge from universities, and many studies conclude that R&D collaboration with universities positively influences firms' innovation. Mansfield (1991) finds that innovations related with university research are introduced more rapidly than others. This implies that R&D collaboration with universities helps enhance the speed of product innovation. Also, innovations that cannot be realized without the support of recent university research

actualize through R&D collaboration with universities (Beise and Stahl, 1999). Belderbos et al. (2004b) conclude that R&D Collaboration with universities positively affects the growth of new-to-the-market sales. Faems et al. (2004) find a positive relationship between university collaboration and the share in firm sales of innovative products new to the market. R&D collaboration with universities is an important instrument in introducing radical innovations to the market and enhancing sales of the products new to the market (Klomp and Van Leeuwen, 2001). Also, R&D collaboration with universities is complementary to other innovation activities such as cooperating with other types of partners, sourcing public information, and performing own R&D (Veugelers & Cassiman, 2005). Based on the various advantages of R&D collaboration with universities on product innovation, we suggest the fourth hypothesis as follows

H4. R&D collaboration with university positively influences firms' product innovation.

3. Methods

3. 1. Data collection

The data for analysis are obtained from the 'Korean Innovation Survey 2005: Manufacturing Sector (KIS),' collected by Science and Technology Policy Institute (STEPI) of South Korea. STEPI made the KIS survey method and questionnaire based on the third edition of Oslo Manual released by the Organization for Economic Cooperation and Development (OECD) to enhance the validity and reliability of answers. KIS data are utilized broadly for research because of the following reasons: its many kinds of variables, and a large set of data. The questionnaire of KIS is made up of 15 pages illustrating important terminologies in the questions. It contains questions on the utilization of each type of R&D collaboration partner, number of product innovation, R&D expenditure, and other questions related to a firm's product innovation.

Population of KIS was extracted from 'Basic statistical survey 2003' of Korea National Statistical Office. STEPI chose 5,378 samples from this population using the Neyman method. Samples were selected by second order stratification. First, STEPI stratified the population on 23 classes according to the Korea Standard Industrial Classification (KSIC). Most firms of Korean manufacturing sectors belonged to the 23 classes. Second, STEPI stratified each category on 5 sub-categories by the number of employees. Then the population was stratified on 115 sub-categories. STEPI determined

the number of samples from each sub-category by the difference of variance between each sub-category. STEPI generated random numbers and randomly selected 5,386 sample firms from 115 sub-categories.

With the exception of 879 firms who had refused to answer the survey, the survey was mailed to 4,507 firms in South Korea. STEPI took back 2,738 answers that amounted up to a response rate of 60.7%. After mailing the survey questionnaire, STEPI followed up with phone calls to sample firms to promote their response. After taking back the answers, STEPI phoned sample firms to verify the result of the survey. In this study we employ a sub-sample of the KIS counting data from 1353 firms that truthfully replied all the questions that are required to this analysis.

3. 2. Variables

3. 2. 1 Dependent variable

This study analyzes the effects of R&D collaboration with different types of partners on product innovation. Previous studies have employed various methods to measure firms' product innovation such as 'fraction of the firm's turnover relating to innovation' (Laursen and Salter, 2006), and 'number of product innovation' (Kang and Kang, 2009). Though Laursen and Salter (2006)'s method is useful in measuring the focal firm's innovativeness, it is not efficient in measuring the quantity of service innovation. We adopt Kang and Kang (2009)'s method for measuring product innovation. This study employs the number of product innovation in 2004 as the measurement of product innovation performance. It is reasonable that the quantity of product innovation represent the level of product innovation performance. KIS 2005 strictly defines product innovation as 'a new product that is completely different from previous products, is commercialized successfully, and affects focal firm's sales'.

3. 2. 2 Independent variables

KIS 2005 defines R&D collaboration as 'Cooperative and interactive R&D or partner's active participation in a focal firm's innovation project'. KIS measures the degree of utilizing R&D collaboration with each type of partner on innovation activities during 2002 to 2004 on a five-point scale (1 to 5): 1 = not useful, 3 = medial, 5 = very useful. Using this method, KIS measures the degree of utilizing R&D collaboration with competitors (CO_COM), with customers (CO_CUSTOM), with suppliers (CO_SUP),

and with universities (CO_UNIV).

3. 2. 3 Control variables

In this study, we employ the following control variables: R&D intensity, firm size, start-up, market size, and industry dummy variables. Because R&D intensity represents not only internal effort for innovation but also absorptive capacity (Cohen and Levinthal, 1990), it has been regarded as an important determinant of innovation performance. We employ R&D intensity to control effects of internal effort and absorptive capacity on product innovation. R&D intensity (RDINT) is determined by focal firm's R&D expenditure divided by firm's sales.

Firm size also affects firm's product innovation, and therefore is frequently employed as a control variable in many research related to innovation. We employ logarithm of the number of total employees who work in focal firms (LOGSIZE) to control the effect of firm size on product innovation.

Since start-up firms tend to innovate more energetically than incumbents, we consider whether or not the firm was a recent start-up (STARUP). If a firm was established in the period 1998-2002, the firm is regarded as a start-up. The variable takes the value of 1 when the focal firm was established in the period 1998-2002; otherwise, it takes the value of 0.

In addition, we control the size of focal firms' product market (GEOMARKET). A firm that operates in large areas should upgrade its product to suit the various needs of different regions. Products competing in the international market become more easily obsolete than products competing in the domestic market; therefore, firms competing in the international market should make more efforts to innovate than firms competing in the domestic market. In this study, GEOMARKET variable takes the value 0 with corresponding to 'domestic market' and 1 corresponding to 'international market'.

3. 3. Method

In this study, we use the number of product innovation in 2004 to measure product innovation. The number of product innovation is a countable integer value. When analyzing a countable dependent variable, researchers can use regression models such as Poisson regression or negative binomial regression. Mean dependent variable is 9.87 and the variance is 43.01. Since the variance of dependent variable is enormously larger than its mean, dependent variable infringes on the basic condition of Poisson

distribution and has an over-dispersion problem. Therefore, we employ negative binomial regression model which allows over-dispersion.

4. Results

This study conducts quantitative analysis employing Korea Innovation Survey 2005 (KIS 2005) collected by STEPI. KIS 2005 is a self self-reported survey, and focal independent variables and the dependent variable were collected by using a single informant and a single survey instrument per firm. Thus, there may be significant risks of single informant bias and common method bias in this study. To address the potential concerns of single informant bias and common method bias, we conducted Harman's (1967) one-factor test. If a substantial amount of common method bias exists in data, either one general factor that accounts for most of the covariance among the variables, or a single factor will come out from the factor analysis will emerge when all the variables are entered together (Podsakoff et al., 2003). Therefore, we entered all the variables into an exploratory factor analysis. An unrotated principal components factor analysis on all the variables generated four factors with eigenvalues greater than 1.0, which together accounted for 53 percent of the total variance; also, the largest factor did not account for a majority of the variance (27%). Therefore, no general factor is apparent. This test left us confident that neither common method nor single informant bias was a serious problem in our study.

<insert table 1 about here>

This study explores the different effects of R&D collaborations with various types of partner on product innovation. Table 1 illustrates summary of descriptive statistics and correlations among variables. It shows relatively high correlations between independent variables. Thus, we conducted variance inflation factor (VIF) analysis to verify whether there is a multicollinearity problem amongst independent variables. Table 2 shows the result of VIF analysis and CO_SUP variable shows the largest value of VIF (1.82). In general, if the VIF value is below than ten, it is accepted that there is no multicollinearity problem. Therefore, relatively high correlation amongst independent variables is not a significant problem. It just represents that a firm who has an open attitude toward R&D collaboration is likely to use various types of partner simultaneously.

<insert table 2 about here>

Table 3 illustrates the results of three negative binomial regression models that analyze the effects of various types of R&D collaboration on product innovation. Each model contains control variables such as RDINT, LOGSIZE, STARTUP, GEOMARKET, and industry dummies. Model 1 is a basic model and contains only the control variables. Model 2 analyzes the linear effects of R&D collaboration with the four partner types (competitors, customers, suppliers, and universities) on product innovation. Model3 contains additional square terms of CO_COM, CO_CUSTOM, CO_SUP, and CO_UNIV to analyze the curvilinear relationship between four independent variables and product innovation.

<insert table 3 about here>

A defect of employing square terms of independent variables to examine quadratic effect is that multicollinearity problem amongst independent variables and its square terms may occur. We compare model 2 and 3 conducing likelihood ratio test to inspect whether or not the multicollinearity problem exists. Because log likelihood of model 2 is -3566.2 and model 3 is -3557.8, the likelihood ratio (LR) value is 16.8. Model 3 contains five additional variables than model 2; thus the degree of freedom is 5. Since the critical value of LR is 11.08 when the degree of freedom is 5 and the LR between model 2 and 3 is greater than the critical value of LR, there is a significant difference between model 2 and model 3. Therefore, it is accepted that there is no significant multicollinearity problem between independent variables and its square terms.

Model 2 shows that the parameter for CO_COM is not significant. However, model 3 shows that the parameter for CO_COM is positive and significant and the parameter for CO_COM squared is negative and significant. Therefore, hypothesis 1 asserting that R&D collaboration with competitors has an inverted-U shape relationship with product innovation is supported.

Model 2 shows that the parameter for CO_CUSTOM is positive and significant. Thus, hypothesis 2 which asserts a positive relationship between R&D collaboration with customers and product innovation is supported. Also, the parameter for CO_UNIV is positive and significant. Therefore, hypothesis 4 asserting that R&D collaboration with universities positively affects product innovation is supported.

However, because the parameter for CO_SUP is not significant, hypothesis 3, which asserts that R&D collaboration with suppliers positively influences product innovation, is rejected. However, model 3 shows that the parameter for CO_SUP is positive and significant and that the parameter for CO_SUP squared is negative and significant. This implies that R&D collaboration with suppliers has inverted-U shape relationship with product innovation. When a firm achieves product innovations, its suppliers should follow the innovations; thereby the suppliers' former capabilities related to previous products may become obsolete. Thus, a firm's innovations could become a crisis to its suppliers, and generate resistance on the suppliers' part toward innovation. This can negatively affect focal firm's product innovation. Some empirical studies show no positive linear relationships or even find negative linear effects (Eisenhardt & Tabrizi, 1995; Hartley et al., 1997; Littler et al., 1998; von Corswant & Tunälv, 2002; Wynstra et al., 2001). It is possible that too strong supplier involvement in innovation activity leads to worse product performance, increased product and development cost, and longer development times.

5. Discussion and conclusion

This research empirically analyzes the effects of four major types of R&D collaboration partners – competitors, customers, suppliers, and universities – on product innovation. Results show that the effect of R&D collaboration on product innovation varies depending on the types of partners. R&D collaborations with customers and universities positively affect product innovation, while R&D collaborations with competitors and suppliers have inverted-U shape relationship with product innovation.

These findings reinforce previous research which assert that firms should consider what types of collaboration partners they select for R&D. Many research conclude that the type of partner is a major factor determining the success and failure of R&D collaboration (Tether, 2002; Fritsch and Lukas, 2001; Belderbos et al. 2004; Fritsch and Franke, 2004; Lhuillery and Pfister, 2009). Each type of partner possesses different resources and capabilities and shows different behavior in R&D collaboration relationship; these differences affect the success and failure of R&D collaboration.

This study grants strategic implication in determining the priority among the types of R&D collaboration partner. The result highlights relative advantages and disadvantages of each type of partners and emphasizes the effect of each type of partners on product innovation. Positive effect of R&D collaboration with customers

and universities on product innovation implies that these types of partners bring much more advantage than disadvantage in product innovation. Therefore, it is generally fruitful for firms to collaborate with customer and universities. However, inverted-U shape relationship between R&D collaboration with particular types of partners on product innovation implies that firms should carefully investigate the causes of negative effects of the partner and execute R&D collaboration prudentially with that type of partner. Therefore, firms should consider collaboration with customers and universities a priority to that with competitors and suppliers for product innovation. It is expected that this study can support firms in selecting their R&D partners more strategically and efficiently.

The finding also contributes to explaining the conflicting results in previous research of R&D collaboration. Many research insist that R&D collaboration positively affects firm's innovation (Aschhoff and Schmidt, 2008; Belderbos et al., 2004a; Cincera et al., 2003; Teng, 2006) while other studies find negative effects (Dyer et al., 2006; Okamuro, 2007; Teng, 2006; Janz etal., 2003). Research asserting the advantages of R&D collaboration are mostly founded on resource based views (Das and Teng, 2000; Dodgson, 1993; Hamel, 1991; Kogut, 1988; Roberts and Berry, 1985), while studies suggesting negative effect of R&D collaboration mainly explain the disadvantages using concepts from organizational behavior perspective such as partners' uncertain behaviors, instability of relationship, and difficulties in executing organizational interaction (Lhuillery and Pfister, 2009; Mora-Valentin et al., 2004; Okamuro, 2007). This study grants an additional explanation for conflicting results. In fact, many previous literatures analyze the effect of R&D collaboration on innovation employing data from single industry to control the effects of different properties between industries. Therefore, it is possible that research analyzing an industry in which firms more frequently collaborate with customers and universities find positive relationship between R&D collaboration and innovation, while research analyzing another industry in which firms more frequently cooperates with competitors and suppliers more likely to conclude that R&D collaboration negatively affects innovation.

This study also contributes to another research that tries to integrate conflicting results of R&D collaboration. Kang and Kang (2009) conclude that the extent of R&D collaboration have inverted-U shape relationship with technology innovation and suggest that firms had better utilize R&D collaboration in moderate level. When firms utilize R&D collaboration in moderate level, firms can select and use particular types of partners that positively affect innovation and maximize the effect of R&D collaboration. However, when firms utilize R&D collaboration more broadly, it is possible that firms

collaborate with other types of partners that show inverted-U shape effect on innovation, and so firm's innovation performance may decrease.

In spite of various advantages, R&D collaboration with competitors has inverted-U shape relationship with product innovation because of high behavioral uncertainties. Therefore, R&D collaboration with competitors should be executed at a moderate and controllable level. R&D collaboration with competitors is more likely to occur in high-tech industries than other industries (Miotti and Sachwald, 2003). Firms in high-tech industries endeavor to enjoy scale of economies and strategic advantage in standardization competition through R&D collaboration with competitors. Because the pace of innovation is faster than other industries, high-tech firms more positively collaborate with competitors and try to obtain synergies from competitors' highly compatible knowledge-base. Also, because high-tech firms have stronger motivation to protect technology and enjoy relatively higher profitability than other industries, the cost for building a monitoring system is not a significant problem in R&D collaboration between high-tech firm and its competitors. However, the opposite situation can occur and converse logic can be applied in traditional industries. Therefore, it is required to consider specific properties of each industry when firms select the type of R&D collaboration partner.

Analyzing the KIS 2005 database has a strong advantage because it grants a large number of samples. However, it is hard to find variables which fit precisely to the object of this research. In this research, we employ the 'number of product innovations in 2004' as a measure of focal firms' product innovation. However, because each product innovation has different extents of innovativeness and different levels of effects on the firm and market, our measurement and findings have limited implication. Also, though KIS 2005 strictly defines the concept of product innovation, each perception of product innovation differs with firms. Therefore, if we can gather data more precisely fitting to our research purpose in future research, we may find a more meaningful result.

Table 1. Descriptive statistics and correlations

Variables	*Mean*	*Std dev.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. CO_COM	0.386	1.082	1							
2. CO_CUSTOM	0.613	1.394	0.4612	1						
3. CO_UNIV	0.531	1.276	0.4868	0.5941	1					
4. CO_SUP	0.647	1.397	0.331	0.3262	0.3863	1				
5. RDINT	4.797	34.224	-0.0016	0.0543	-0.0082	0.0566	1			
6. LOGSIZE	4.815	1.258	0.1377	0.1524	0.1437	0.1476	-0.0913	1		
7. STARTUP	0.114	0.319	0.0305	-0.0118	-0.0243	-0.0502	0.1322	-0.2055	1	
8. GEOMARKET	0.639	0.480	0.0559	0.0611	0.0571	0.0734	0.029	0.2458	-0.044	1

Table2. VIF Test results

Variables	*VIF*
1. CO_RIVAL	1.46
2. CO_CUSTOM	1.70
3. CO_SUP	1.82
4. CO_UNIV	1.28
5. RDINT	1.04
6. LOGSIZE	1.23
7. STARTUP	1.09
8. GEOMARKET	1.13
평균	1.34

Table 3. Negative binomial regression, explaining relationship of R&D collaboration partners and innovation performance

Model	Ⅰ		Ⅱ		Ⅲ	
Dep. variable	PRODUCT INNOVATION		PRODUCT INNOVATION		PRODUCT INNOVATION	
Indep. variable	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
CO_COM			0.0086	0.06133	0.3789**	0.1952
CO_COM^2					-0.0982**	0.0463
CO_CUSTOM			0.1104**	0.0502	0.2522	0.1738
CO_CUSTOM^2					-0.0407	0.0399
CO_SUP			0.0326	0.05875	0.4178**	0.1901
CO_SUP^2					-0.0992**	0.042582
CO_UNIV			0.1400***	0.04198	-0.0405	0.1694
CO_UNIV^2					0.0349	0.0393
RDINT	0.0014	0.0016	0.0014	0.0016	0.0014	0.0012
LOGSIZE	0.4992***	0.0431	0.4688***	0.0434	0.4773***	0.0437
STARTUP	-0.2148	0.1727	-0.1961	0.1728	-0.1450	0.1729
GEOMARKET	0.1468	0.1169	0.1135	0.1144	0.1047	0.1138
Industry dummies	Yes		Yes		Yes	
No. of obs	1353		1353		1353	
Log likelihood	-3857.7		-3566.2		-3557.8	
Chi-square	320.70***		363.64***		380.52***	

*p < 0.10; ** p < 0.05; *** p < 0.01

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