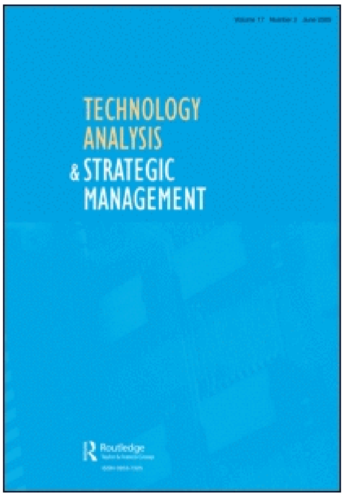

Technology Analysis & Strategic Management
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713447357

Does partner type matter in R&D collaboration for product innovation?

Ki H. Kang[a]; Jina Kang[a]
[a] Technology Management, Economics and Policy Program, Seoul National University, South Korea

Online publication date: 21 October 2010

To cite this Article Kang, Ki H. and Kang, Jina(2010) 'Does partner type matter in R&D collaboration for product innovation?', Technology Analysis & Strategic Management, 22: 8, 945 — 959
To link to this Article: DOI: 10.1080/09537325.2010.520473
URL: http://dx.doi.org/10.1080/09537325.2010.520473

Technology Analysis & Strategic Management
Vol. 22, No. 8, November 2010, 945–959

Does partner type matter in R&D collaboration for product innovation?

Ki H. Kang and Jina Kang*

Technology Management, Economics and Policy Program, Seoul National University, South Korea

Most firms tend to utilise 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 Korean 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. This result can provide an explanation to the chaotic results of previous research and assist managers in selecting appropriate R&D partner.

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; Keil 2002); particularly, the R&D collaboration that allows firms to combine internal and external resources and capabilities occupies a crucial position in innovation strategies (Bailey, Masson and Raeside 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; Tyler and Steensma 1995).

With the increasing importance of R&D collaboration in innovation, many researchers have intensively explored factors affecting the success of R&D collaboration (Belderbos, Carree and Lokshin 2004; Fritsch and Lukas 2001; Tether 2002). In particular, recent research identifies the type of R&D collaboration partner as a critical factor determining the effect of R&D collaboration on innovation (Belderbos, Carree and Lokshin 2004; Fritsch and Franke 2004; Fritsch

*Corresponding author. Email: profkang@snu.ac.kr

ISSN 0953-7325 print/ISSN 1465-3990 online

DOI: 10.1080/09537325.2010.520473
http://www.informaworld.com

and Lukas 2001; Lhuillery and Pfister 2009; Tether 2002). 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 behaviour 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 analyse the effects of R&D collaborations with various partner types on innovation have shown confusing and chaotic results (Aschhoff and Schmidt 2008; Belderbos, Carree and Lokshin 2004; Fritsch and Franke 2004; Lhuillery and Pfister 2009). For example, Belderbos, Carree and Lokshin (2004) 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 analyse 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 utilising R&D collaboration with each type of partner within a single empirical model. The effects of four types of R&D collaboration partners are analysed by employing the negative binomial regression model. We utilise the 'Korean 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, Carree and Lokshin 2004). Previous research suggests 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 (Dodgson 1993; Hamel 1991), diversifying firms' technological competence (Das and Teng 2000), granting advantages of scope and scale of economies (Kogut 1988), 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 (Aschhoff and Schmidt 2008; Belderbos, Carree and Lokshin 2004; Faems, Van Looy and Debackere 2004; Lööf and

Heshmati 2002), while others prove a negative relationship (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 has intensively explored the factors affecting R&D collaboration performance (Bailey, Masson and Raeside 1998; Belderbos, Carree and Lokshin 2004; Bruce et al. 1995; Fritsch and Lukas 2001; Hakanson and Lorange 1991; Lhuillery and Pfister 2009; Miotti and Sachwald 2003). 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, Carree and Lokshin 2004; Fritsch and Franke 2004; Fritsch and Lukas 2001; Lhuillery and Pfister 2009; Tether 2002). Most firms utilise 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 behaviour 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, Carree and Lokshin (2004) 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.

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 analyse 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.

While previous studies have considered various types of R&D partners, only three – customers, suppliers and competitors – are universally included (Aschhoff and Schmidt 2008; Belderbos, Carree and Lokshin 2004; Fritsch and Franke 2004). This reflects a common understanding that R&D collaborations with these three types of partners have significant effects on firm's innovation and competitive advantage. For a firm to sustain a competitively advantageous position in this innovation-based environment, R&D collaborations with horizontal competitors in the same market may have a significant effect on the firm's innovation and performance. For a firm to continue its production and sales activities, transactional relationships with its vertical partners, i.e. customers and suppliers, are incurred. When the firm strengthens this 'transactional relationship'

Table 1. Chaotic relationships between types of partner and innovation in previous research

Research	Measure of innovation	Model	Customers	Suppliers	Competitors	Research institutes	University	Business service firms
Aschhoff and Schmidt (2008)	Share of sales with improved/new to the firm products	Tobit	No	No	No	No		
	Share of sales new to the market	Tobit	No	No	No	+		
Belderbos et al. (2004)	Growth innovative sales productivity	OLS	No	No	+	No	+	No
Fritsch and Franke (2004)	Patent: whether or not	Logit	No	No	+	+		No
	No. of patents	Negative binomial	−	No	No	No		No

Notee: +: positive relationship; −: negative relationship; No: no significant relationship; Blank: not considered in analysis to a 'collaborative relationship', it would have a significant effect on the firm's innovation and performance. Therefore, R&D collaboration with competitors, customers and suppliers necessitates further research.

This study additionally considers R&D collaboration with universities. Unlike the aforementioned three types of partners, universities are entities external to the industry, and possess considerably dissimilar types of knowledge, resources and capabilities. This means that the R&D collaboration between the firm and universities may incur a new type of relationship, which would have unique effect on the firm. Therefore, studying the effect of R&D collaborations with universities on product innovation can provide a new understanding of the firm and its activities. Since this research uses data from the South Korean manufacturing sector which boasts of active industry–university collaborations (Lim 1999), it provides an ideal opportunity for observing effects of R&D collaborations with universities on firm product innovation.

These are the reasons why this study looks closely at competitors, customers, suppliers and universities. Immediately below, we intensively investigate the properties of R&D collaborations with four types of R&D partners and empirically analyse 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 Scandinavian peninsula. A firm and its direct competitors 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 (Aschhoff and Schmidt 2008; Belderbos, Carree and Lokshin 2004; Lööf and Heshmati 2002). Also, firms can share the risk and cost of large-scale R&D projects (Miotti and Sachwald 2003). Belderbos, Carree and Lokshin (2004) find that collaborations with rivals improve firms' productivity. Because improvement of efficiency of production helps firms acquire financial and organisational 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 (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 and tends to occur more frequently in R&D collaboration between competitors (Hamel 1991; Oxley and Sampson 2004). Competitors have a stronger motive for opportunistic behaviour, such as change of the objective of R&D collaboration and illegal transfer of core technology, than other types of partners (Bruce et al. 1995; Dodgson 1993; Pisano 1990). Therefore, partners who compete with each other in the market show very uncertain behaviour, which can generate delay and failure in R&D projects. Thus it is possible that R&D collaboration between competitors negatively influences 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. The generally low proportion of firms collaborating with competitors (compared with the proportion of firms collaborating with other types of partners) is indicative of the difficulties in managing partnerships with competitors (Röller, Tombak and Siebert 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.

Hypothesis 1. R&D collaboration with competitors has an 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% of German entrepreneurial firms maintain a collaborative relationship with customers (Fritsch and Franke 2004). Relatedness of customers to innovation significantly affects innovation performance and knowledge creation (Rothwell et al. 1974; Von Hippel 1988; Weck 2006). R&D collaboration with customers especially influences product innovation (Aschhoff and 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 products (Von Hippel 1988). Information obtained from customers contributes to the sales growth of innovative products (Belderbos, Carree and Lokshin 2004). It also helps diffusion of innovative products and contributes to success of product innovation (Belderbos, Carree and Lokshin 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 an 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 the second hypothesis as follows.

Hypothesis 2. 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 partner. R&D collaboration with suppliers improves the efficiency of firms' product development. R&D collaboration with suppliers reduces unnecessary rework (Loch and Terwiesch 1998), enables firms to efficiently set up the schedule of product development (Tannenbaum, Beard and Salas 1992), supports the integration of the operation process between firms and suppliers through knowledge sharing (Barratt 2004), and allows firms to solve technological problems quickly in the process of product development

(Katz 1982). Previous research also asserts that supplier involvement on product development shortens the time to market, enhances quality, reduces costs and increases a firm's ability to achieve R&D projects (Wynstra, VanWeele and Weggemann 2001).

Since suppliers who provide product components are strongly related with their buyer firms on the same value chain, firms and their suppliers have strongly connected needs of product innovation. Firms and their suppliers should know and understand each other to intimately integrate a product and its components for successful product innovation. R&D collaboration can aid firms and their partners 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 firms for product innovation (Hoegl and Wagner 2005; Littler, Leverick and Wilson 1998), and thus firms and their suppliers exchange their information smoothly (Littler, Leverick and Wilson 1998; Ragatz, Handfield and Petersen 2002).

In addition, R&D collaboration with suppliers enhances the efficiency of production. Collaborations with suppliers reinforce firms' supply chains that are comprised of procurement, production and distribution (Fawcett and Magnan 2002). Belderbos, Carree and Lokshin (2004) empirically show that R&D collaboration with suppliers enhances firms' productivity. Because improvement of efficiency helps firms acquire financial and organisational 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.

Hypothsis 3. 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, Caraca and Diz 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, Caraca and Diz 2006). Firms approach universities for the purpose of exploring knowledge and expertise, and firms in knowledge-based technology sectors that show a strong desire for new technology build partnerships with universities more frequently (Hanel and St-Peirre 2006).

Firms can innovate by utilising 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 realised without the support of recent university research actualise through R&D collaboration with universities (Beise and Stahl 1999). Belderbos, Carree and Lokshin (2004) conclude that R&D collaboration with universities positively affects the growth of new-to-the-market sales. Faems, Van Looy and Debackere (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 the firm's own R&D (Veugelers and Cassiman 2005).

Based on the various advantages of R&D collaboration with universities on product innovation, we suggest the fourth hypothesis as follows.

Hypothesis 4. 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 the Science and Technology Policy Institute (STEPI) of South Korea. STEPI produced the KIS survey method and questionnaire based on the third edition of the *Oslo Manual* released by the Organisation for Economic Cooperation and Development (OECD) to enhance the validity and reliability of answers. KIS data are utilised broadly for research because of 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 utilisation of each type of R&D collaboration partner, number of product innovations, 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 5378 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 Korean Standard Industrial Classification (KSIC). Most firms of Korean manufacturing sectors belonged to the 23 classes. Second, STEPI stratified each category on five 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 5386 sample firms from 115 sub-categories.

With the exception of 879 firms who had refused to answer the survey, the survey was mailed to 4507 firms in South Korea. STEPI took back 2738 answers that gave 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 receiving the answers, STEPI phoned sample firms to verify the result of the survey. In this study we employed a sub-sample of the KIS, counting data from 1353 firms that truthfully replied to all of the questions that were required for this analysis.

3.2. *Variables*

3.2.1. *Dependent variable*

This study analyses 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 'share of sales relating to innovation' (Aschhoff and Schmidt 2008), 'Growth innovative sales productivity' (Belderbos, Carree and Lokshin 2004), and 'number of product innovations' (Kang and Kang 2009). Aschhoff and Schmidt's (2008) and Belderbos, Carree and Lokshin's (2004) methods are useful in measuring the focal firm's relative innovativeness; however, it is not efficient in measuring the absolute quantity of product innovations. Therefore, we adopt Kang and Kang's (2009) method for measuring product innovation performance. This study employs the number of product innovations in 2004 as the measurement of product innovation performance. KIS 2005 strictly defines product innovation as 'a new product that is completely different from previous products, is commercialised successfully, and affects focal firm's sales'. Thus, it is reasonable that the quantity of product innovations represent the level of product innovation performance.

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 measured the degree of utilising R&D collaboration with each type of partner on innovation activities during 2002–2004 on a five-point scale (1 to 5): 1 = not useful, 3 = medial, 5 = very useful. Using this method, KIS measured the degree of utilising 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 employed R&D intensity to control effects of internal effort and absorptive capacity on product innovation. R&D intensity (RDINT) was determined by the focal firm's R&D expenditure divided by the firm's sales.

Firm size also affects the firm's product innovation and therefore is frequently employed as a control variable in most research related to innovation. We employed the 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 (STARTUP). 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 the 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 effort to innovate than firms competing in the domestic market. In this study, the GEOMARKET variable takes the value 0 corresponding to the 'domestic market' and 1 corresponding to the 'international market'.

3.3. *Method*

In this study, we use the number of product innovations in 2004 to measure product innovation. The number of product innovations is a countable integer value. When analysing a countable dependent variable, researchers can use regression models such as Poisson regression or negative binomial regression. The mean of the dependent variable is 9.87 and the variance is 43.01. Since the variance of the dependent variable is considerably larger than its mean, the dependent variable infringes on the basic condition of Poisson distribution and has an over-dispersion problem. Therefore, we employed a negative binomial regression model that allows for over-dispersion.

Table 2. Descriptive statistics and correlations

Variables	Mean	SD	1	2	3	4	5	6	7
1. CO_COM	0.386	1.082	1						
2. CO_CUSTOM	0.613	1.394	0.461	1					
3. CO_UNIV	0.531	1.276	0.487	0.594	1				
4. CO_SUP	0.647	1.397	0.331	0.326	0.386	1			
5. RDINT	4.797	34.224	−0.002	0.054	−0.008	0.057	1		
6. LOGSIZE	4.815	1.258	0.138	0.152	0.144	0.148	−0.091	1	
7. STARTUP	0.114	0.319	0.031	−0.012	−0.024	−0.050	0.132	−0.206	1
8. GEOMARKET	0.639	0.480	0.056	0.061	0.057	0.073	0.029	0.248	−0.044

Note: SD = standard deviation.

4. Results

This study conducts quantitative analysis employing the Korean 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% 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.

This study explores the different effects of R&D collaborations with various types of partner on product innovation. Table 2 illustrates a 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 among independent variables. Table 3 shows the result of VIF analysis and the CO_SUP

Table 3. VIF Test results

Variables	VIF
1. CO_COM	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
Average	1.34

Table 4. Negative binomial regression, explaining relationship of R&D collaboration partners and innovation performance

Model	I		II		III	
Dependent variable	Product innovation		Product innovation		Product innovation	
Independent variable	Coef.	SE	Coef.	SE	Coef.	SE
CO_COM			0.0086	0.06133	0.3789**	0.1952
CO_COMˆ2					–0.0982**	0.0463
CO_CUSTOM			0.1104**	0.0502	0.2522	0.1738
CO_CUSTOMˆ2					−0.0407	0.0399
CO_SUP			0.0326	0.05875	0.4178**	0.1901
CO_SUPˆ2					−0.0992**	0.042582
CO_UNIV			0.1400***	0.04198	−0.0405	0.1694
CO_UNIVˆ2					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 observations	1353		1353		1353	
Log likelihood	−3857.7		−3566.2		−3557.8	
χ^2	320.70***		363.64***		380.52***	

Notes: $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$. SE: standard error.

variable shows the largest value of VIF (1.82). In general, if the VIF value is lower than ten, it is accepted that there is no multicollinearity problem. Therefore, a relatively high correlation among independent variables is not a significant problem. It just represents that a firm that has an open attitude toward R&D collaboration is likely to use various types of partner simultaneously.

Table 4 illustrates the results of three negative binomial regression models that analyse 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 analyses the linear effects of R&D collaboration with the four partner types (competitors, customers, suppliers and universities) on product innovation. Model 3 contains additional square terms of CO_COM, CO_CUSTOM, CO_SUP and CO_UNIV to analyse the curvilinear relationship between the four independent variables and product innovation.

A defect of employing square terms of independent variables to examine the quadratic effect is that a multicollinearity problem among independent variables and their square terms may occur. We compare models 2 and 3 conducing the likelihood ratio test to inspect whether or not the multicollinearity problem exists. Because the 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 more variables than model 2; thus the degree of freedom is 5. Since the critical value of *LR* ($p = 0.05$) is 11.08 when the degree of freedom is 5. Because 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 their 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 an 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 cause a crisis for its suppliers and generate resistance on the suppliers' part toward innovation. This can negatively affect the focal firm's product innovation. Some empirical studies show no positive linear relationships or even find negative linear effects (Littler, Leverick Wilson 1998; Wynstra, VanWeele and Weggemann 2001). It is possible that a 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 analyses 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 an 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. Much research concludes that the type of partner is a major factor in determining the success and failure of R&D collaboration (Belderbos, Carree and Lokshin 2004; Fritsch and Franke 2004; Lhuillery and Pfister 2009). Each type of partner possesses different resources and capabilities and shows different behaviour in the R&D collaboration relationship; these differences affect the success and failure of R&D collaboration.

This study provides a 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 partner and emphasises the effect of each type of partner on product innovation. A positive effect of R&D collaboration with customers and universities on product innovation implies that these types of partner bring many more advantages than disadvantages in product innovation. Therefore, it is generally fruitful for firms to collaborate with customers and universities. However, an inverted-U shape relationship in R&D collaboration with particular types of partner on product innovation implies that firms should carefully investigate the causes of the negative effects of the partner and execute R&D collaboration prudently with that type of partner. Therefore, firms should consider collaboration with customers and universities a reater priority than that with competitors and suppliers for product innovations. It is expected that this study could support firms in selecting their R&D partners more strategically and efficiently.

The finding also contributes to explaining the conflicting results in previous research on R&D collaborations. Much research insists that R&D collaboration positively affects a firm's innovation (Aschhoff and Schmidt 2008; Lööf and Heshmati 2002) while other studies find negative effects (Okamuro 2007; Teng 2006). 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), while studies suggesting a negative effect of R&D collaboration mainly explain the disadvantages using concepts from an organisational behaviour perspective such as partners' uncertain behaviours, instability of relationships and difficulties in executing organisational interaction (Lhuillery and Pfister 2009; Okamuro 2007). This study provides an additional explanation for conflicting results. In fact, much of the previous literature on the subject analyses the effect of R&D collaboration on innovation employing data from a single industry to control the effects of different properties between industries. Therefore, it is possible that research analysing an industry in which firms more frequently collaborate with customers and universities find positive relationships between R&D collaboration and innovation, while research analysing another industry in which firms more frequently cooperate with competitors and suppliers is 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 has an inverted-U shape relationship with technology innovation and suggest that firms had better utilise R&D collaboration at a moderate level. When firms utilise R&D collaboration at a moderate level, firms can select and use particular types of partners that positively affect innovation and maximise the effect of R&D collaboration. However, when firms utilise R&D collaboration more broadly, it is possible that firms collaborate with other types of partners that show an inverted-U shape effect on innovation, and so firms' innovation performance may decrease.

In spite of various advantages, R&D collaboration with competitors has an inverted-U shape relationship with product innovation because of high behavioural uncertainties. Therefore, R&D collaboration with competitors should be executed at a moderate and controllable level. R&D collaborations with competitors are more likely to occur in high-tech industries than other industries (Miotti and Sachwald 2003). Firms in high-tech industries endeavour to enjoy a scale of economies and strategic advantage in standardisation 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 their 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 firms and their competitors. However, a 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.

Analysing the KIS 2005 database has a strong advantage because it grants a large number of samples. However, it is hard to find variables that 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, our future research may produce more meaningful results.

Notes on contributors

Ki H. Kang is a PhD candidate of the Technology Management, Economics and Policy Program (TEMEP) at Seoul National University (SNU). His current research interests focus on the characteristics of R&D cooperation and technology outsourcing, and their impact on technological innovation. His broad interests span technology innovation, knowledge management, firm networks and firm strategies.

Jina Kang is a professor of Technology Management Economics and Policy Program and the Industrial Engineering Department of Seoul National University. She received her PhD in Management from the University of California, Los Angeles (UCLA). Her works have appeared in journals such as *R&D Management* and *Journal of Knowledge Management*. Her current research focuses on innovation and knowledge transfer in firm networks.

References

Aschhoff, B. and T. Schmidt. 2008. Empirical evidence on the success of R&D cooperation: Happy together? *Review of Industrial Organization* 33: 41–62.

Bailey, W.J., R. Masson and R. Raeside. 1998. Choosing successful technology development partners: A best-practice model. *International Journal of Technology Management* 15, no. 1–2: 124–38.

Barratt, M. 2004. Understanding the meaning of collaboration in the supply chain. *Supply Chain Management* 9, no. 1: 30–42.

Beise, M. and H. Stahl. 1999. Public research and industrial innovations in Germany. *Research Policy* 28, no. 4: 397–422.

Belderbos, R., M. Carree and B. Lokshin. 2004. Cooperative R&D and firm performance. *Research Policy* 33: 1477–92.

Belderbos, R., M. Carree and B. Lokshin. 2006. Complementarity in R&D cooperation strategies. *Review of Industrial Organization* 28, no. 4: 401–26.

Bruce, M., L. Fiona, L. Dale and W. Dominic. 1995. Success factors for collaborative product development: A study of suppliers of information and communication technology. *R&D Management* 25, no. 1: 33–44.

Chesbrough, H.W. 2003. *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business School Press.

Cohen, W.M. and D.A. Levinthal. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35, no. 1: 128–52.

Das, T.K. and B.S. Teng. 2000. A resource-based theory of strategic alliances. *Journal of Management* 26, no. 1: 31–60.

Dodgson, M. 1993. *Technological collaboration in industry*. London: Routledge.

Faems, D., B. van Looy and K. Debackere. 2004. The role of interorganizational collaboration within innovation strategies: Towards a portfolio approach. *Journal of Product Innovation Management* 22, no. 3: 238–50.

Fawcett, S.E. and G.M. Magnan. 2002. The rhetoric and reality of supply chain integration. *International Journal of Physical Distribution & Logistics* 32, no. 5: 339–61.

Fritsch, M. and G. Franke. 2004. Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy* 33, no. 2: 245–255.

Fritsch, M. and R. Lukas. 2001. Who cooperates on R&D? *Research Policy* 30: 297–312.

Geringer, J.M. and L. Hebert. 1989. Control and performance of international joint ventures. *Journal of International Business Studies* 20, no. 2: 235–54.

Hagedoorn, J. 1993. Understanding the rationale of strategic technology partnering: Interorganisational modes of co-operation and sectoral differences. *Strategic Management Journal* 14: 371–85.

Hagedoorn, J. 2002. Inter-firm R&D partnerships: An overview of major trends and patterns since 1960. *Research Policy* 31: 477–92.

Hakanson, L. and P. Lorange. 1991. R&D based co-operative ventures. In *Corporate and Industry Strategies for Europe*, ed. L.G. Matsson and B. Styme, 235–63. Amsterdam: North-Holland.

Hamel, G. 1991. Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management Journal* 12: 83–103.

Hanel, P. and M. St-Peirre. 2006. Industry–university collaboration by Canadian manufacturing firms. *Journal of Technology Transfer* 31: 485–99.

Harman, H.H. 1967. *Modern factor analysis*. Chicago, IL: University of Chicago Press.
Hoegl, M. and S.M. Wagner. 2005. Buyer–supplier collaboration in product development projects. *Journal of Management* 31, no. 4: 530–48.
Kang, K.H. and J. Kang. 2009. How do firms source external knowledge for innovation? Analyzing effects of different knowledge sourcing methods. *International Journal of Innovation Management* 13, no. 1: 1–17.
Katz, R. 1982. The effects of group longevity on project communication and performance. *Administrative Science Quarterly* 22: 81–104.
Keil, T. 2002. *External corporate venturing: Strategic renewal in rapidly changing industries*. Westport, CT: Quorum.
Klomp, L. and G. van Leeuwen. 2001. Linking innovation and firm performance: A new approach. *International Journal of the Economics of Business* 8, no. 3: 343–64.
Kogut, B. 1988. Joint ventures: Theoretical and empirical perspectives. *Strategic Management Journal* 9, no. 4: 319–32.
Lhuillery, S. and E. Pfister. 2009. R&D cooperation and failures in innovation projects: Empirical evidence from French CIS data. *Research Policy* 38: 45–57.
Lim, Y. 1999. *Technology and productivity: The Korean way of learning and catching up*. Cambridge, MA: MIT Press.
Littler, D., F. Leverick and D. Wilson. 1998. Collaboration in new technology based product markets. *International Journal of Technology Management* 15: 139–59.
Loch, C.H. and C. Terwiesch. 1998. Communication and uncertainty in concurrent engineering. *Management Science* 44: 1032–48.
Lööf, H. and A. Heshmati. 2002. Knowledge capital and performance heterogeneity: A firm-level innovation study. *International Journal of Production Economics* 76, no. 1: 61–85.
Mansfield, E. 1991. Academic research and industrial innovation. *Research Policy* 20: 1–12.
Marques, J.P.C., J.M.G. Caraca and H. Diz. 2006. How can university–industry–government interactions change the innovation scenario in Portugal? – The case of the University of Coimbra. *Technovation* 26: 534–42.
Miotti, L. and F. Sachwald. 2003. Co-operative R&D: Why and with whom? An integrated framework of analysis. *Research Policy* 32: 1481–99.
Okamuro, H. 2007. Determinants of successful R&D cooperation in Japanese small businesses: The impact of organizational and contractual characteristics. *Research Policy* 36, no. 10: 1529–44.
Oxley, J.E. and R.C. Sampson. 2004. The scope and governance of international R&D alliances. *Strategic Management Journal* 25, no. 8–9: 723–49.
Pisano, G.P. 1990. The R&D boundaries of the firm: An empirical analysis. *Administrative Science Quarterly* 35: 153–76.
Podsakoff, P.M., S.B. MacKenzie, J.Y. Lee and N.P. Podsakoff. 2003. Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology* 88: 879–903.
Ragatz, G.L., R.B. Handfield and K.J. Petersen. 2002. Benefits associated with supplier integration into new product development under conditions of technology uncertainty. *Journal of Business Research* 55: 389–400.
Röller, L.H., M.M. Tombak and R. Siebert. 1997. *Why firms form research joint ventures: theory and evidence*. Vol. 1654. Berlin: Social Science Center WZB.
Rothwell, R., C. Freeman, A. Horsley, V.T.P. Jervis, A.B. Robertson and J. Townsend. 1974. SAPPHO updated: Project SAPPHO phase II. *Research Policy* 3: 258–91.
Tannenbaum, S.I., R.L. Beard and E. Salas. 1992. Teambuilding and its influence on team effectiveness: An examination of conceptual and empirical developments. In *Issues, theory, and research in industrial/organizational psychology*, ed. K. Kelley, 117–53. Amsterdam: Elsevier
Teng, B.S. 2006. Corporate entrepreneurship activities through strategic alliances: A resource-based approach toward competitive advantage. *Journal of Management Studies* 44: 119–42.
Tether, B.S. 2002. Who co-operates for innovation, and why: An empirical analysis. *Research Policy* 31, no. 6: 947–67.
Tyler, B.B. and H.K. Steensma. 1995. Evaluating technological collaborative opportunities: A cognitive modelling perspective. *Strategic Management Journal* 16: 43–70.
Veugelers, R. and B. Cassiman. 2005. R&D cooperation between firms and universities: Some empirical evidence from Belgian manufacturing. *International Journal of Industrial Organization* 23: 355–79.
Von Hippel, E. 1988. *The sources of innovation*. New York: Oxford University Press.
Weck, M. 2006. Knowledge creation and exploitation in collaborative R&D projects: Lessons learned on success factors. *Knowledge and Process Management* 13: 252–63.
Wynstra, F., A. vanWeele and M. Weggemann. 2001. Managing supplier involvement in product development: Three critical issues. *European Management Journal* 19: 157–67.