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Determinants of Selection of R&D Cooperation Partners: Insights from Korea

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Abstract: These days, small and medium-sized enterprises (SMEs) face more severe competition in foreign markets due to the globalization of the economy (e.g., FTA). They usually lack technological capabilities and often depend on external R&D activities. Thus, it is worth exploring what factors facilitate SMEs' R&D collaboration with partners. This paper empirically analyzes the determinants of SMEs' selections of R&D cooperation partners in Korea. According to the regression results, SMEs with a larger labor force in R&D, larger sales, younger CEOs, more advanced technologies, and less R&D equipment are more likely to cooperate with external R&D partners. When SMEs produce a product that is not easily imitated by others, they are more willing to cooperate with universities or research institutions but not with suppliers or customers. In sum, for Korean SMEs, the arguments of appropriability and resource complementarity appear to work in their R&D activities. However, the former is more important for collaborations with universities or research institutions, and the latter is more influential to those with suppliers and customers. This paper contributes to the literature in two aspects—quantitative studies on the collaborative innovation of SMEs are still limited, and the differences in cooperation determinants across types of partners are explored due to the richness of the dataset.

Keywords: R&D collaboration; SME; appropriability; resource complementarity

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1. Introduction

In Korea, the employment share of small and medium-sized enterprises (hereafter, SMEs) remains as high as it was in 2018, when it reached 90.2%. However, their sales occur mostly in the domestic market (i.e., 88.6%), and they take up just 18.6% of the total exports of Korea. Moreover, 14 FTAs have been effective in Korea since 2006, and they cause SMEs in Korea to confront harsher business environments than ever before.

SMEs often try to overcome their lack of management capabilities with a comparative advantage in technologies by allotting a relatively larger portion of their budget to R&D activities. They invested USD 11.2 billion in 2012, 20.2% of the national R&D investment, which has had a 15.4% annual growth rate over the last 10 years. There has been a rise in the share of R&D performers among small and medium-sized manufacturing firms from 19.5% in 2004 to 31.0% in 2012. In addition, the R&D-related employment in SMEs reached 110,677 workers in 2012, equivalent to 5.3% of the SME workforce.

This drastic change in SMEs' R&D activities was possible partly due to the Korean government's efforts. The Korean government has financially supported SMEs and recently implemented a policy for co-growth and cooperation between large and small firms, especially in R&D activities. For instance, the Korean government budget for SMEs' R&D activities in 2014 was about USD 605.2 million. In 2004, the foundation for co-growth between large and small firms was established, and a law intended to promote co-growth was legislated in 2006. Specifically, a policy that prevents technology theft and appropriation was implemented in 2010, aiming to invigorate technical collaborations and alliances between large and small firms.

Nevertheless, there seems to be no remarkable change in SME collaborations on R&D projects. Ironically, these policy efforts would imply that the R&D cooperation of SMEs in Korea is not as active as in developed countries. Firms are likely to collaborate in R&D activities for potential spillovers and the interest in sharing costs and risks [1,2]. Specifically, SMEs often lack the capacity and human resources to absorb external knowledge and confront financial constraints [3]. Moreover, since technological life cycles have become shorter, and the costs and risks of activities related to innovation have become larger, SME R&D collaboration has become an important mechanism to obtain external knowledge [4].

The main purpose of this paper is to suggest policy measures that enable SMEs to more actively participate in open R&D to improve their technological competitiveness. Thus, we empirically analyzed the determinants of partner selection for SMEs' R&D cooperation in Korea. We identified the factors that affect SMEs' R&D cooperation decisions based on binary logit model results and examined which characteristics of SMEs determine their choice of partners from results based on a multinomial logit model. In the multinomial logit model, the partners were classified into two groups: one for universities and research institutions and the other for suppliers and customers. As the determinants, characteristics and the innovation of SMEs were considered. More specifically, the theoretical arguments on appropriability and resource complementarity were tested. Regarding the latter, we looked at the possible non-linearity, which has not yet been fully explored in the literature.

This paper contributes to the limited literature regarding quantitative studies on the collaborative innovation of SMEs [5–7]. In addition, drawing upon a rich dataset, which includes 3300 firms, the binary choice of R&D cooperation with external partners, as well as the multiple choice of partner selection, is analyzed.

Section 2 reviews previous studies on the determinants of SMEs' R&D cooperation and defines the hypotheses of this study. Section 3 explains the analytical model and the data used for regression analyses with descriptive statistics of the variables. Empirical findings are presented in Section 4 and discussed in Section 5. Section 6 concludes with key findings, policy implications, limitations, and suggestions for future research.

2. Literature Review

Regarding the innovative cooperation of firms, there are four areas of interest, namely the motives that cause firms to participate in cooperation, the selection of partners, the management of cooperation, and the measurement of cooperation performance [8]. Inflow and outflow of knowledge spillovers at the firm level, the size of firms, R&D intensity, and high costs as barriers are considered to be determinants of the first two areas. Together with these firm-level factors, the degree of market concentration at the industry level and country- or region-specific factors, including country size, intellectual property regime, and public policies, are often taken into account. In addition, dyadic attributes, such as technology overlap and similarity in size, are included.

Firms collaborate on R&D activities for various reasons. SMEs are often characterized as having insufficient R&D-related resources, weak management capabilities, and deficient marketing channels for new products, lacking the driving force for new technology development. According to Wassmer [9], resource complementarity, quests for power, and the potential for synergistic value creation are key factors. Meanwhile, Adobor [10] argued that social structures also play important roles in alliance formation, and firms' relational experiences assist in the formation of future ties.

A firm's decision on collaborative R&D is affected by knowledge sharing through which internal innovation is accelerated, as well as by concerns for protecting tacit knowledge. That is, the degree to which the intended exchange of knowledge occurs and intellectual properties are protected has an influence on firms' open innovation efforts. For example, Sprakel and Machado [11] showed that firms make relatively more use of appropriation mechanisms when their inbound and outbound flow difference is small.

However, Freel and Robson [12] showed that only informal intellectual property protection mechanisms are associated with an increasing extent of inbound open innovation. Similarly, Cassiman and Veugelers [1] emphasized the role of incoming spillover and appropriability. Two arguments, including transaction cost economics and the resource-based view of the firm, provide theoretical backgrounds on firms' behavior related to their R&D collaborations. According to the former, collaboration manages asset specificity, which leads to switching costs, lowers the uncertainty of specifying and monitoring partners' performance, internalizes spillovers, balances the partners' contributions, and mitigates opportunistic behavior [5]. Collaboration is one of the strategies that can be taken when firms have to externalize their technology sourcing to deal with market uncertainties [13]. Uncertainty and the risk of opportunistic behavior by partners are regarded as the main obstacles to R&D cooperation [14–16]. Meanwhile, the resource-based view argues that collaborations can be used to exploit resource complementarities. Thus, the motives for collaboration and partner selection are the exploitation of resource complementarity and economies of scale, obtaining benefits from low costs in entering new markets, risk management, tacit collusion, and capability enhancement and learning. Jee and Sohn [17], using a patent-based framework, suggested how entrepreneurial firms could leverage their limited resources and manage the tension between learning and protection in partner selection. Knowledge belongs to one of the overwhelmingly important productive resources and its tacitness determines its transferability [18]. For knowledge as a resource, imitability plays an important role in relation to appropriability [19]. However, knowledge is required to be explicit for participants in an R&D collaboration to benefit from increasing returns to scale because knowledge is characterized to be inter-dependent and cumulative [20].

Based on the literature, two hypotheses are tested. First, cooperation is often disaggregated into three types by partner: institutional, vertical, and horizontal cooperation. Comparing institutional and vertical cooperation, the arguments of appropriability apply to the former to a greater extent. R&D cooperation with universities or research institutions is likely to include a science-based component at the early stage of a technology. The R&D result could be utilized by other firms due to the generic nature of the innovation. Thus, collaboration occurs only when there is less risk of appropriation by outsiders of the R&D arrangement. However, vertical cooperation (i.e., R&D cooperation with suppliers and customers) usually happens for an applied component which is specific only to the product or production process at the mature stage in its life cycle. The necessity of resource complementarity is theoretically argued for in the growth of SMEs. However, the exact relationship between R&D cooperation and resource complementarity has remained an open question. This is the second hypothesis of this paper. There would be a non-linear relationship between R&D cooperation and absorptive capacity. As the share of SMEs' own equipment increases, the probability to cooperate in R&D would rise in the beginning, but with a decreasing rate. Thus, the resource complementarity argument would hold on a conditional basis.

Both theoretically and empirically, appropriability seems to be important for SMEs' R&D cooperation decisions. Additionally, many studies have already shown that SMEs tend to participate in R&D cooperation more actively when there is larger appropriability. However, the relationship between appropriability and SMEs' R&D cooperation decisions and partner selections, considering both the nature of technology (science-based vs. market-based) and type of collaboration (institutional vs. vertical), is still scarcely explored in the literature [21]. With science-based technology which relies more heavily on advances in basic research, there would be more appropriability in R&D cooperation since competitors confront a greater difficulty in imitating the result of the cooperation. Additionally, R&D cooperation on science-based technology has a tendency to be performed between universities or research institutions and SMEs. However, SMEs lack R&D resources and thus use R&D equipment from universities or (public) research institutions. Thus, if the resource complementarity is not controlled for in the analyses of SMEs, the effect of appropriability on SMEs' R&D cooperation decisions would be overestimated.

3. Methods and Materials

In order to suggest policy measures for the increase in SMEs' technological competitiveness through collaborative R&D, it is required to find the factors that affect SMEs' decisions on R&D cooperation and selection of partners. In particular, this paper aims to explore the importance of appropriability and resource complementarity as key determinants of SMEs' R&D activities.

3.1. Analytic Models

To analyze the determinants of SMEs' R&D cooperation partner selections, two models are estimated: one for the decision to participate in open R&D cooperation or not, and one for the decision of what kind of partner to select. A binary logit model is applied to the former, while the latter is based on a multinomial logit model.

The main hypothesis of this paper is tested by estimating the following regression equation:

$$Y_j = b_0 + b_1 S_j + X_j c + \sum_{k=1}^{16} d_k \ region_{jk} + \sum_{l=1}^{29} h_l \ industry_{jl} + u_j \quad (1)$$

Here, for the binary logit model, Y_j indicates whether firm j cooperates in R&D with partners or not. S_j includes proxy variables for the firm's appropriability and resource complementarity. X_j controls for the firm's characteristics such as life cycle of technology, workforce in R&D, sales, CEO's age, and gender. $region_{jk}$ and $industry_{jl}$ are the metropolitan city/province where the firm is located and the two-digit industry to which the firm belongs, respectively. u_j represents the usual error term. Meanwhile, for the multinomial logit model, Y_j is either 0 for no cooperation, 1 for institutional cooperation, or 2 for vertical cooperation.

3.2. Data

For the empirical analyses, this paper draws upon the Survey on Technology of SMEs which includes information on R&D activities, type of organization, employment, level of technology, and so on for samples of small and medium-sized firms mainly in the manufacturing sector. The population consists of SMEs having at least 5 and less than 300 workers and belonging to manufacturing or business service industries. The dataset, concerning the year 2015, includes 3300 firms of which 2463 are manufacturing firms. The data belong to a statutory statistical survey in accordance with Article 8 of the Small and Medium Business Technology Innovation Promotion Act. The survey is conducted by the Small and Medium Business Administration and the Korea Federation of Small and Medium Enterprises, which are government agencies, and the survey is approved by the Statistics Office of Korea. Thus, the data are reliable and have been used for academic papers and policy reports.

The summary statistics of variables are shown in Table 1. The life cycle of the technology owned by SMEs is defined by four stages: introduction, growth, maturity, and decline. About half of the sample belongs to the maturity stage and 39.9% to the growth stage. These shares are similar to those of SMEs who do not cooperate in R&D activities. However, SMEs with collaborative R&D projects show a relatively higher share of firms at the growth stage. The average number of workers in R&D is slightly more than 6, and cooperating firms have a larger labor force in R&D than non-cooperating firms do. Additionally, cooperating firms have a relatively larger volume of sales in monetary value. The CEOs are male in 92% of the firms and 53 years old on average. These two characteristics of CEOs are very similar in cooperating and non-cooperating firms.

Firms have, on average, 8 patents, and cooperating firms seem to have more patents than non-cooperating firms with a difference of nearly 4 patents. About 48% of firms are certified as venture, and venture firms are more likely to collaborate with partners to develop a new product or production process. In relation to imitability of the technology, approximately 63% of firms have technologies which could be copied within one year. Technologies owned by cooperating firms seem to be more complex than those owned by non-cooperating firms. About half of firms own less than 50% of equipment required to perform R&D activities.

Table 1. Summary statistics of variables.

Variable	Sample Mean (N = 3300)	Mean, Cooperating Firms (N = 779)	Mean, Non-Cooperating Firms (N = 2521)
Life cycle of technology			
Introduction	0.072	0.059	0.075
Growth	0.399	0.445	0.385
Maturity	0.511	0.484	0.519
Decline	0.018	0.012	0.020
Workers in R&D	6.27	8.19	5.68
Sales	13.70	17.25	12.61
Characteristics of CEO			
Male	0.923	0.932	0.920
Age	53.13	53.22	53.10
Patent	8.30	11.19	7.41
Non-venture	0.521	0.418	0.553
Time required to be copied			
Less than 3 months	0.074	0.041	0.084
3 to 5 months	0.205	0.157	0.221
6 to 11 months	0.347	0.321	0.355
12 to 17 months	0.208	0.262	0.192
18 to 23 months	0.085	0.113	0.077
24 months or more	0.080	0.107	0.071
Share of own equipment			
None	0.109	0.073	0.120
Positive but less than 25%	0.218	0.207	0.221
25 to 49%	0.189	0.230	0.176
50 to 74%	0.219	0.249	0.209
75 to 99%	0.165	0.195	0.155
100%	0.101	0.046	0.117

4. Empirical Results

4.1. Choice of Open R&D

Table 2 presents the estimation results for the determinants of an SME's R&D cooperation decision based on binary logit models. Column (1) considers only the firm-specific factors that would affect its decision to cooperate on R&D activities with partners. For Columns (2) through (5), variables that measure appropriability and resource complementarity are additionally included. The last two columns show the results per type of R&D alliance, distinguishing between institutional and vertical cooperation.

According to the results in Column (1)–(3), the likelihood of firms collaborating on R&D activities does not differ significantly across the stages of the technology life cycle. However, firms that are larger in terms of R&D-related labor force or sales have a higher propensity to work together with partners. In the literature, the number of workers in R&D is often used to measure the degree of absorptive capacity. Thus, this result supports the argument that SMEs with more capacity to absorb external knowledge are more likely to collaborate with partners. Cantabene and Grassi [7], based on Italian data, also found that human capital facilitates an SME's R&D cooperation. While there is no statistically significant difference in performing open R&D between female and male CEOs, younger CEOs tend to cooperate more.

When an SME has more patents to protect its technologies from being copied illegally, it is expected to be more willing to collaborate on R&D projects. However, the result in Column (2) does not support this argument empirically. If firms are more competitive in technologies, they tend to be less concerned about the appropriability of the outcome from the collaborative R&D project. The fact that an SME is certified as a venture firm signals that it has more advanced technologies. The result in Column (3) is consistent with this theoretic argument. Firms with technologies which are more complex or advanced, and thus less likely to be copied, have a greater tendency to collaborate on R&D projects. At the same time, firms with less equipment for R&D activities have a higher probability to co-work with partners on R&D. These findings imply that, in Korea, the behavior of SMEs in R&D collaborations and alliances could be explained in terms of transaction cost economics and also from a resource-based view. However, the result in Column (4) shows a non-linear relationship. As the share of own equipment for R&D increases, the probability to cooperate with universities or research institutions rises. However, once the share is greater than 50%, the probability falls, and the relationship becomes reversed, changing from positive to negative in the end.

The last two columns show the results where R&D collaborations are classified into two types: institutional vs. vertical collaborations. Imitability of the technology appears to be significantly influential to institutional collaborations (i.e., an SME's cooperation with universities or research institutions) but not to vertical ones (i.e., cooperation with suppliers and customers).

Table 2. Binary logit model: probability of participating in open R&D.

	(1)	**(2)**	**(3)**	**(4) Institutional Cooperation**	**(5) Vertical Cooperation**
Life cycle of technology					
Introduction	−0.0563	−0.0688	−0.0606	0.0823	−0.1079
	(−0.30)	(−0.35)	(−0.31)	(0.48)	(−0.32)
Growth	0.2358 +	0.2043	0.1931	0.3961 *	0.0558
	(1.72)	(1.56)	(1.48)	(2.37)	(0.34)
Decline	−0.2896	−0.2619	−0.2041	0.1012	−0.5360
	(−0.69)	(−0.61)	(−0.47)	(0.23)	(−0.99)
Workers in R&D	0.0208 **	0.0184 **	0.0180 **	0.0227 **	0.0097 *
	(2.97)	(2.93)	(2.61)	(3.38)	(2.08)
Sales	0.0068 *	0.0071 *	0.0075 *	0.0079 *	0.0094 **
	(2.36)	(2.24)	(2.31)	(2.30)	(3.01)
Characteristics of CEO					
Male	0.0336	−0.0041	0.0058	−0.0167	0.1464
	(0.21)	(−0.03)	(0.04)	(−0.10)	(0.94)
Age	−0.0067 +	−0.0072 +	−0.0068 +	−0.0055	−0.0033
	(−1.76)	(−1.84)	(−1.73)	(−0.88)	(−0.49)
Patent		0.0009			
		(0.53)			

Non-venture			−0.3614 **	−0.4110 *	−0.3781 *
			(−2.82)	(−2.56)	(−2.22)
Time required to be copied					
3 to 6 months		0.1820	0.1763	0.4074	0.0919
		(0.61)	(0.59)	(1.27)	(0.36)
6 to 12 months		0.3981	0.4207	0.7283 *	0.3350
		(1.08)	(1.14)	(2.05)	(0.88)
12 to 18 months		0.6282 $^{+}$	0.6479 $^{+}$	0.8961 *	0.4928
		(1.73)	(1.79)	(2.48)	(1.59)
18 to 24 months		0.6767 $^{+}$	0.6659	0.9900 **	0.4539
		(1.65)	(1.63)	(2.67)	(1.05)
At least 24 months		0.7339 $^{+}$	0.7225 $^{+}$	0.9944 **	0.4230
		(1.71)	(1.72)	(2.61)	(0.89)
Share of own equipment					
Less than 25%		0.3452 *	0.3333 *	0.2674	0.3783
		(2.06)	(1.98)	(1.30)	(1.24)
25 to 50%		0.5273 **	0.5058 **	0.5886 **	0.5829 $^{+}$
		(2.88)	(2.89)	(3.67)	(1.66)
50 to 75%		0.3687 $^{+}$	0.3128	0.4950 **	0.1835
		(1.82)	(1.55)	(3.87)	(0.46)
75 to 99%		0.1966	0.1323	0.2990 $^{+}$	0.1615
		(1.25)	(0.77)	(1.85)	(0.41)
100%		−0.8455 **	−0.8717 **	−0.7174 **	−0.8254 **
		(−3.83)	(−3.87)	(−2.84)	(−2.59)
Constant	−1.5479 **	−2.3288 **	−2.0852 **	−2.8339 **	−3.1698 **
	(−3.08)	(−4.57)	(−4.29)	(−4.11)	(−8.01)
Pseudo R-squared	0.0679	0.0906	0.0945	0.110	0.0891
Log likelihood	−1681	−1640	−1633	−1320	−1101

Note. Numbers in parentheses are White–Huber's robust t-values with an assumption that errors are correlated within a region. **, *, and $^{+}$ indicate statistical significance at 1%, 5%, and 10%, respectively. The reference group for the life cycle of technology is the maturity stage. The number of observations (i.e., SMEs) is 3300. Dummy variables for 2-digit industries and regions, respectively, are included in the regression, but their coefficients are suppressed due to limited space.

4.2. R&D Partner Selection

Table 3 reports the multinomial logit model results where the base outcome is no collaboration on R&D. While the results in Table 2 only showed which factors affect Korean SMEs' binary choices on whether to collaborate with partners on R&D projects or not, those in Table 3 present how the factors affect the partner selection. When its workforce is larger, an SME is more likely to collaborate no matter who is the partner. However, SMEs with relatively larger sales tend to cooperate with suppliers and customers but not with universities or research institutions. This asymmetric result also appears with the age of CEOs. An older CEO is less likely to work together with universities or research institutions.

In Column B, three explanatory variables are added, as in Table 2, in order to address the theoretic issues discussed in Section 2. Non-venture firms seem to be less likely to collaborate both with universities or research institutions and with suppliers and customers. For R&D projects where the technology or information is more difficult, and thus more time is required to be copied, SMEs tend to prefer universities or research institutions to suppliers or customers as a partner. The resource complementarity argument seems to be more compatible with SMEs' collaboration in R&D with suppliers and customers rather than with universities or research institutions.

Table 3. Multinomial logit model: probability of cooperating R&D activities with given partners.

	A		**B**	
	Institutional Cooperation	**Vertical Cooperation**	**Institutional Cooperation**	**Vertical Cooperation**
Life cycle of technology				
Introduction	0.009	−0.106	0.022	−0.116
	(0.06)	(−0.31)	(0.12)	(−0.33)
Growth	0.372 *	0.118	0.331 +	0.073
	(2.13)	(0.68)	(1.92)	(0.45)
Decline	0.085	−0.657	0.162	−0.533
	(0.18)	(−1.14)	(0.31)	(−0.97)
Workers in R&D	0.022 **	0.020 **	0.019 **	0.017 *
	(2.91)	(2.74)	(2.79)	(2.29)
Sales	0.005	0.009 *	0.005	0.009 *
	(1.26)	(2.57)	(1.27)	(2.55)
Characteristics of CEO				
Male	−0.103	0.175	−0.138	0.163
	(−0.54)	(0.97)	(−0.76)	(0.99)
Age	−0.010 *	−0.003	−0.010 *	−0.003
	(−2.21)	(−0.51)	(−1.96)	(−0.50)
Non-venture			−0.305 *	−0.421 *
			(−2.41)	(−2.45)
Time required to be copied				
3 to 6 months			0.204	0.175
			(0.49)	(0.66)
6 to 12 months			0.453	0.409
			(1.22)	(1.02)
12 to 18 months			0.690 +	0.618 +
			(1.65)	(1.80)
18 to 24 months			0.796 +	0.577
			(1.90)	(1.26)
At least 24 months			0.875 *	0.577
			(2.06)	(1.16)
Share of own equipment				
Less than 25%			0.221	0.449
			(1.14)	(1.47)
25 to 50%			0.342 *	0.643 +

			(1.97)	(1.87)
50 to 75%			0.388 *	0.268
			(2.19)	(0.68)
75 to 99%			0.128	0.175
			(0.73)	(0.45)
100%			−0.745 *	−1.026 **
			(−2.11)	(−3.34)
Constant	−2.080 **	−2.608 **	−2.617 **	−3.187 **
	(−3.59)	(−4.67)	(−3.54)	(−9.24)
Pseudo R-squared	0.0784	0.0784	0.100	0.100
Log likelihood	−2158	−2158	−2107	−2107

Note. Numbers in parentheses are White–Huber's robust t-values with an assumption that errors are correlated within a region. **, *, and + indicate statistical significance at 1%, 5%, and 10%, respectively. The reference group for the life cycle of technology is the maturity stage. The number of observations (i.e., SMEs) is 3300. Dummy variables for 2-digit industries and regions, respectively, are included in the regression, but their coefficients are suppressed due to limited space.

5. Discussion

SMEs need to have technological competitiveness to survive in an increasingly competitive global market. However, they lack capabilities and resources for their own technological innovation. Thus, R&D cooperation with external partners is one of their options. According to the analysis results presented in this paper, both appropriability of the benefits from R&D cooperation and resource complementarity appear to increase the possibility of SMEs to engage in R&D cooperation with external partners. In particular, the results show that appropriability is important in R&D cooperation with universities or research institutions because this type of cooperation is mainly practiced in science-based R&D which occurs at the early stage of the innovation process. Similarly, Becker and Dietz [22] showed that innovation input and output are enhanced by collaborative R&D at the early stage. However, Weber and Heidenreich [21] found that cooperation with institutional partners is the most important throughout the whole innovation process. Science-based R&D is not limited to a specific product or production process and can be applied to a variety of products and production processes, so it could be used by third-party companies that are not involved in the R&D cooperation, especially competitors. Therefore, SMEs have less incentives for R&D cooperation due to concerns about free-riding. From a policy perspective, it is necessary to strengthen the systems and devices that protect SMEs' benefits from R&D cooperation. However, Miozzo et al. [23] found that formal appropriability mechanisms, such as patents, copyrights, and trademarks, are important for capturing value from innovation, while Freel and Robson [12] showed that informal mechanisms, such as lead-time, secrecy, and complexity, are effective. Belderbos et al. [24], drawing upon data on Spanish innovative firms, empirically showed that firms with strong prior innovative performance establish R&D collaborations with new partners, but not with competitors, because they fear leakage of proprietary knowledge to rivals.

In the case of R&D cooperation for enhancing the complementarity of resources, the related literature suggests that firms with poor R&D resources achieve technological innovation through cooperation. However, according to the empirical results of this paper, which measures the complementarity of resources by the ratio of own equipment to total equipment required for R&D, the likelihood that SMEs cooperate in R&D appears to be the highest when the ratio is 25–50%. This trend is especially evident in technical cooperation with suppliers and customers. In the end, this implies that government support is needed for SMEs to have the minimum equipment or facilities in order to activate their R&D cooperation. Recently, Reuer and Devarakonda [25] pointed out that venture capitalists could facilitate R&D partner selection by playing a role as information intermediator and thus strengthening resource complementarity among R&D collaboration participants.

6. Conclusions

6.1. Summaries and Policy Recommendations

The rapid development of the Korean economy during the 1970s and 1980s is often contributed to the large industrial conglomerates, so called Chaebol. However, with the fast change in technologies related to lifestyles, including production and consumption, the role of SMEs which could easily reflect this trend in their products or production processes has been emphasized. Meanwhile, there exist some restrictions on this role because these firms especially lack R&D-related capabilities and resources. Even though some SMEs often collaborate with partners on R&D projects to overcome their restrictions, SMEs' participation in open R&D is still limited due to various reasons.

This paper has empirically analyzed the determinants of SMEs' selection of R&D cooperation partners in Korea. According to the regression results, SMEs with a larger labor force in R&D, larger sales, younger CEOs, more advanced technologies, and less R&D equipment are more likely to cooperate with external R&D partners. When SMEs produce a product that is not easy to be imitated by others, they are more willing to cooperate with universities or research institutions but not with suppliers and customers. In sum, the arguments of appropriability and resource complementarity appear to apply to the R&D activities of Korean SMEs. However, the former is more important for the collaborations with universities or research institutions, and the latter is more influential for those with suppliers and customers. Similarly, Lewandowska [26] showed that SME competitiveness is dependent upon the expenditures on machinery and equipment for innovation activities.

In Korea, a huge amount of the public budget is spent on helping SMEs' R&D activities. However, the effectiveness of this is often questionable. Thus, it is necessary to design a policy that facilitates effective cooperation on R&D activities between SMEs and their potential partners. As policy tools, public subsidies, tax credits, matching and networking, SME-friendly intellectual property rights, and public procurement of innovative products could be considered. More specifically, regarding patent application, policies that lower the fee, shorten the inspection duration, and simplify the administration process would be helpful for SMEs' R&D cooperation with relatively higher appropriability. Moreover, the findings show that SMEs' R&D cooperation, especially with suppliers and customers, is most active when they own 25 to 50% of the equipment required for R&D. Thus, to be most efficient, public subsidies encouraging SMEs' R&D collaboration need to be concentrated on those firms.

6.2. Limitations and Future Research

This paper has some drawbacks that could be addressed in future work. First of all, it ignores the role of tacit knowledge that comes from the business environment of the region where a SME is located. Although the regression equation includes dummy variables for 16 metropolitan cities and provinces, this is not sufficient to control for the heterogeneity of local areas since tacit knowledge often occurs from unintended and informal face-to-face contacts within walking distance. Tojeiro-Rivero and Moreno [27] showed that firms located in knowledge-intensive regions obtain higher returns of cooperation in terms of innovation performance. Additionally, as another type of open R&D, horizontal cooperation is not considered due to data limitations. By leveraging the mutual capabilities and resources through horizontal cooperation, firms could share risks, realize economies of scale and scope, and improve productivity. Ko et al. [28] found that firms who cooperate with competitors at the value creation stage have relatively higher R&D productivity.

In follow-up research, the innovation performance of SMEs who participate in collaborative R&D needs to be investigated and compared with that of SMEs without open R&D. Public support for SMEs' R&D cooperation is only justifiable when SMEs show relatively better performance with open R&D rather than with closed R&D. For instance, Jiang et al. [29] showed that SMEs could improve their technology standard-setting capability through collaborative R&D and enhance their economic efficiency. In addition, Albors-Garrigos et al. [30] considered the role of research technology organizations as leaders or facilitators of R&D collaboration with SMEs and the performance measured by their innovation output and their turnover per employee. Lastly, studying high-tech companies from the German B-2-B sector, Weber and Heidenreich [21] found that cooperation is beneficial to companies in general and significantly improves innovation capabilities and success of a company regardless of the type of cooperation.

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