The Contribution of R&D Investment to Productivity in the South Korean Service Sector

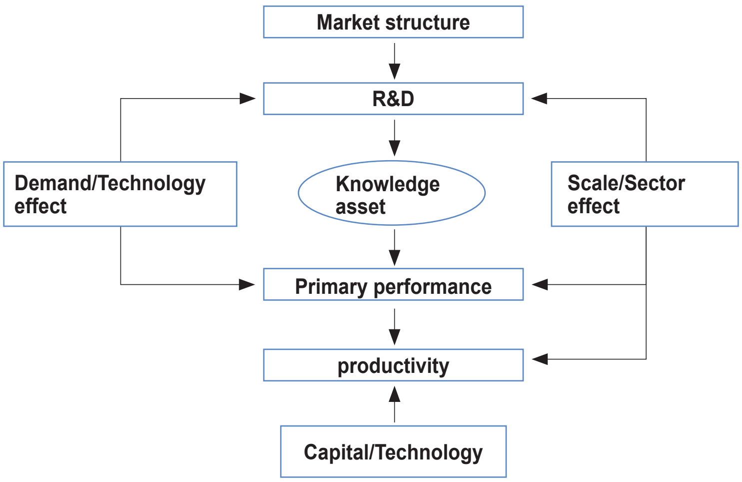
1. Overview

The purpose of corporate R&D investment is to improve productivity, and the way in which R&D investment increases productivity was structured very effectively by Crepon et al (1998).[1)] This model is called the CDM model and first stage of the process is the choice of R&D investment by firms affected by the market structure.

The selected R&D investment in the firm has formed a knowledge asset and this is the source of primary innovation performance, such as patents or sales of the innovative product. Finally, investment in R&D leads to higher productivity of companies. This procedure is expressed as the following figure.

The CDM is an econometrics model based on this concept and describes the main axis from market structure to productivity in the conceptual diagram (figure 1) of the path of R&D investment to productivity. Considering the situation of a company in relation to R&D, an enterprise faces a choice through

Figure 1. Diagram of CDM Model



Source: Crepon B. et al. (1998).

1) Crepon, B., Emmanuel Duguet and Jaques Mairesse, "Research, innovation and productivity: An econometric analysis at the firm level", *Economics of Innovation and New Technology*, Vol. 7, 1998, pp. 115-158.

managerial judgment: whether to invest in R &D or not. In the next step, if the company chooses R&D investment, is to decide how much to invest in R&D. In the conceptual diagram, these two processes lead from market structure to research and development. R&D investment comprises a firm's intellectual assets, which is actually a primary form of innovation, the aforementioned patents and sales of innovative products. However, the CDM model is characterized by the fact that the ultimate goal of investment in R&D is to improve corporate productivity, and not just primary innovation performance.

This CDM model consists of three steps. In the first stage, a corporation considering its management environment determines whether to invest in R&D (or not) and the amount of that investment. The second stage is about producing knowledge assets and primary innovation performance, and the final step is to ensure that innovation performance is indicative of increased productivity. The first step is represented by two different metrics that determine R&D investment itself and the amount of investment in R&D. Therefore, all three CDM models are estimated with four metrics.

These CDM models have been used empirically in Loof and Heshmati (2002, 2006)[2] and Oh IH et al. (2008).[3] These studies are based on the Community Innovation Survey (CIS) that originated from the OECD's methodology of innovation survey. These papers analyzed the CDM model for manufacturing companies in Sweden and Korea. Investment in R&D was found to have a positive effect on primary innovation performance and productivity. Griffith, R. et al. (2006)[4] Hall, B.H., et al. (2009)[5] and OECD (2009)[6] have also published notable research papers on CDM model.

The CDM model, which is mainly utilized in analyses of manufacturing companies, has also been studied for service companies as interest in R&D and service industry innovation has increased. A case study of the CDM model based on the CIS or similar survey of the service industry can be found in Garcia-Pozo, A. et al (2018)[7], De Fuentes, C. et al.

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2) Loof, H. and Almas Heshmati, "Knowledge capital and performance heterogeneity: A firm-level innovation study", *International journal of production economics*, Vol. 76, 2002, pp. 61-85.
——, "On the Relationship between Innovation and Performance: A Sensitivity Analysis", *Economics of Innovation and New Technology*, Vol. 15 (4/5), 2006, pp. 317-344.

3) Oh, I. H., S. Han and Almas Heshmati, "The relationship between innovation and performance of Korean manufacturing firms", in Heshmati A. and J.D. Lee (Eds), "Micro-evidence for the Dynamics of Industrial Revolution: The Case of the Manufacturing Industry in Japan and Korea", Nova Science Publishers, 2008.

4) Griffith, R., Elena Huergo, Jacques Mairesse and Bettina Peters, "Innovation and productivity across four European countries", *Oxford Review of Economic Policy*, Vol. 22, No. 4, 2006, pp. 483-498.

5) Hall, Bronwyn H., Francesca Lotti and Jacques Mairesse, "Innovation and productivity in SMEs: Empirical evidence for Italy", *Small Business Economics*, Vol. 33, 2009, pp. 13-33.

6) OECD, "Innovation in firms: A microeconomic perspective", OECD, Paris, 2009.

7) Garcia-Pozo, A., Andres J. Marchante-Mera, and Juan A. Campos-Soria, "Innovation, environment, and productivity in the Spanish service sector: An implementation of a CDM structural model", *Journal of Cleaner Production*, Vol. 171, 2018, pp. 1049-1057.

(2015)[8] and Masso, J., Vahter, P. (2012).[9] They found, using a CDM analysis of a CIS survey in Spain, Mexico and Estonia that investment in product innovation during innovation processes in service sector firms positively affects corporate productivity. But as of yet there are no empirical studies to analyze the performance of Korean service firms' R&D through the CDM methodology.

2. Econometric Analysis of CDM Model

The first step in an analysis of the CDM model, which seeks to determine ideal R&D investment, is to ensure to avoid sample selection bias. In other words, when analyzing the amount of investment in R&D, it a mistake to exclude companies that have chosen not to invest in R&D. This would cause sample selection bias in the regression results. In order to solve this problem, the Heckman sample selection model, which analyzes two-stage regression models or the Tobit model for the censored sample data would be adopted for an appropriate regression methodology. In this paper, the first stage of the CDM model is analyzed with the Cragg model, which is a revised Tobit model (William J. Burke, 2009).[10]

The first step of the CDM model with a sample selection problem is expressed as the following equation.

〈Equation 1〉

$$y_i = y_i^* \text{ if } y_i^* > 0$$
$$y_i = 0 \text{ if } y_i^* \leq 0$$
$$\text{where, } y_i^* = \alpha_1 + X_i\beta + \varepsilon_i$$

In this equation, y is the amount of innovation investment per employee and y* is a latent variable which is not observed. For each observations, y has value of zero if the latent variable has a value less than 0 and if the latent variable has value of 0 or more, y has the observed value. Alpha refers to the constant and beta is a symbol for the parameter vector. Xi stands for a variable vector representing observation characteristics. It is assumed sigma follows the standard normal distribution with an average of zero and a standard deviation of sigma. The following equation is a typical Tobit model for the analysis of the censored sample by constructing an estimation equation that includes both latent variable values of 0 or less and 0 or more.

〈Equation 2〉

$$f(y|x) = \{1 - \Phi(x\beta/\sigma)\}^{1(y=0)} \left[(2\pi)^{-\frac{1}{2}}\sigma^{-1}exp\{-(y - x\beta)^2/2\sigma^2\}\right]^{1(y>0)}$$

8) De Fuentes, C., Gabriela Dutrenit, Fernando Santiago and Natalia Gras, "Determinants of Innovation and Productivity in the Service Sector in Mexico", *Emerging Markets Finance and Trade*, Vol. 51, No. 3, 2015, pp. 578-592.

9) Masso, J. and Priit Vahter, "The link between innovation and productivity in Estonia's services sector", The Service Industries Journal, Vol. 32, No. 16, 2012, pp. 2527-2541.

10) Burke, William J., "Fitting and interpreting Cragg's tobit alternative using Stata", The Stata Journal, Vol. 9, No. 4, 2009, pp. 584-592.

The biggest problem with the Tobit model is that it assumes that the influence of variables is identical regardless of the level of latent variables. In the Cragg model, the following equation is used to relax the constraint.

⟨Equation 3⟩

$$y_i = y_i^* \text{ if } y_i^* > 0$$
$$y_i = 0 \text{ if } y_i^* \leq 0$$
$$\text{where, } y_i^* = \alpha_1 + X_1\beta_1 + X_2\beta_2 + \varepsilon_i$$

⟨Equation 4⟩

$$f(y|x_1, x_2) = \{1 - \Phi(x_1\beta_1)\}^{1(y=0)} \ [\Phi(x_1\beta_1) (2\pi)^{-\frac{1}{2}}\sigma^{-1} exp\{-(y - x_2\beta_2)^2/2\sigma^2\}/ \Phi(x_2\beta_2/\sigma)]^{1(y>0)}$$

As implied in the equation, the probability that the observed value is 0 and the probability of it being positive is determined by different variables and parameters. In other words, in the Cragg model, the explanatory variable X has subsets of X1 and X2 depending on the R&D investment situation. It is also the same as parameter beta 1 which explains a case in which the observation value is 0, and beta2, which explains the case of it having a positive value. Since the setting of the Cragg model relaxes the constraints assumed by the Tobit model, the special case of the Cragg model becomes the Tobit model. That is, the Cragg model is the same as Tobit model, when the parameter beta1 equals beta2/sigma and the explanatory variable is the same (x1 = x2). After estimating the Cragg model using the maximum likelihood estimation, the probability of R&D investment could be calculated as follows.

⟨Equation 5⟩

$$p(y_i = 0|x_{1i}) = 1 - \Phi(x_{1i}\beta_1)$$
$$p(y_i > 0|x_{1i}) = \Phi(x_{1i}\beta_1)$$

In addition, the conditional average value of R&D investment (when firms do in fact choose to invest in R&D) is defined as follows.

⟨Equation 6⟩

$$E(y_i|y_i > 0, x_{2i}) = x_{2i}\beta_2 + \sigma \times \lambda(x_{2i}\beta_2/\sigma)$$

Where lambda is the inverse Mill's ratio (thereafter IMR) derived from the sample selection of the Hekman model by dividing the probability density value of the standard normal distribution by the cumulative probability density value of the standard normal distribution. IMR represents the probability that each observation is excluded from the analysis and represents sample selection bias in analyzing the behavior of an innovation investment. Finally, the average predictive value of the choice to invest in innovation and the subsequent amount of said investment amount is defined by the following equation.

⟨Equation 7⟩

$$E(y_i|x_{1i}, x_{2i}) = \Phi(x_{1i}\beta_1)\{x_{2i}\beta_2 + \sigma \times \lambda(x_{2i}\beta_2/\sigma)\}$$

In this way, the first two steps of the CDM model dealing with the decision on innovation investment are estimated with all firms in the sample regardless of whether or not they have invested in innovation. The figure from Equation 7 is the expected value of a company's R&D investment. The second stage of the CDM model is modeling the process of creating primary innovation performance through the formation of knowledge assets. In this second stage the results obtained from the two estimates of the first stage are included as explanatory variables. First, the inverse Mill's ratio (IMR, expressed as lambda in Equation 7), which describes the selection bias in the decision phase of innovation investment, is included to compensate for the bias of sample selection. The second estimate to include as an explanatory variable is the expected value of innovation investment amount. This variable compensates for the endogeneity problem of the innovation investment variables. Reflecting these characteristics, the estimation of the second stage is expressed by the following equation.

〈Equation 8〉

$$S_i = \alpha_2 + \beta_{MR}\hat{\lambda}_i + \beta_S \hat{E}(y_i | x_{1i}, x_{2i}) + \beta_3 X_3 + \varepsilon_i$$

In equation 8, Si represents the primary innovation performance of firm i, and the explanatory variables are constant (alpha 2), IMR (lambda i), the expected value of R&D investment per employee (E hat), and other characteristic variables of the company (denoted by X3).

In analyzing the second stage of the CDM model, we need to look at what primary innovation performance is. For example, in Garcia-Pozo, A. (2018), a dummy variable representing successful innovation results is used as primary innovation performance. Loof H. and Heshmati A. (2002) and OECD (2009) have considered the sales ratio of innovative products as primary performance. In this study, the contribution of sales by product innovation in service, in other words, sales by product innovation divided by total sales, was used to reflect primary innovation performance. In this analysis, I use the revenue from innovative products as an explained variable, an approach adopted in most studies based on CIS surveys. More precisely, the sales by service product innovation per employee is used as the explained variable. In this way, the estimation equation for the second stage of the CDM model, primary innovation performance (or creation of knowledge assets), is estimated with the sample of firms performing innovation activities.

The third stage of the CDM model is to estimate the impact of primary innovation performance (per capita sales by innovation) on firm productivity. As in the case of the estimation equation of the second stage, where the expected value of innovation investment and IMR as estimated in previous steps are included as explanatory variables, the final stage of estimation includes the expected value of primary innovation performance estimated in the second stage as an explanatory variable. This also assists in bias correction arising from endogeneity. In other words, in considering the trajectory of R&D investment to productivity, the endogeneity of innovation performance is corrected with the stepwise estimation procedures. The estimation equation of the final stage is expressed by the following equation.

〈Equation 9〉

$$Z_i = \alpha_3 + \beta_S \hat{E}(s_i | x_{1i}, x_{2i}, , x_{3i}) + \beta_4 X_4 + \varepsilon_i$$

Here, Zi is the final result of innovation, productivity. The constant term is expressed as alpha 3. The expected value of primary innovation performance (E hat) estimated in second stage and other company characteristics (X4) are included as explanatory variables. For the explained variable, sales per employee and labor productivity are used separately. In addition, the above equation is estimated with a sample of companies performing innovation activities as in the second step of the estimation formula.

3. Data and Variables

(1) Data for the Analysis

For the Empirical Study, the 2016 Version of the Korea Innovation Survey (KIS) from the Science and Technology Policy Institute (STEPI) was used. This survey is composed of 4,000 service and manufacturing companies, respectively. In the service sector, 2,268 companies replied that they did not perform innovation activities, while 1,732 companies said that that did perform innovation activities in the period from 2013 to 2015. The corporate database of Nice Investors Service Co., was adopted to compensate for missing and erroneous quantitative figures related to the business environment in the KIS. That data included corporate sales, exports, the number of permanent employees, and the cost of innovation activities. These figures take Nice Investors Service DB as a priority, and such data does not exist, it is supplemented by data from the KIS. In the case of innovation investment costs, ordinary research and development expenses and ordinary development expenses are summed in determining total R&D cost.

In the final stage of the CDM model, the value added per worker — that is, labor productivity — is an essential variable. However, the data for the calculation of value added per-capita are not included in KIS. Therefore, the value added of the company was calculated by using Nice Investors Service Co.'s database. Specifically, the sum of labor costs and operating profit was used as the value added of the company.

(2) Variables for Estimations

1) Dependent Variables

For the explained variables of the two estimation equations in the first stage of the CDM model, the innovation activity variable and (per employee) innovation investment were used. Innovation activity is a dummy variable that has a value of 1 if the service product or process innovation has performed, or if there are or have been innovation activities left uncompleted or abandoned. It has value of 0 in other cases. The amount of per-employee innovation investment uses log-transformed values. The expected value of the innovative investment that could be estimated as a result of the first stage will be used as an explanatory variable in the second stage estimation of the CDM model.

In the second step, the explained variable (sales of service goods through innovation per employee) is log scale transformed. This is a variable that represents the primary outcome of the innovation activity and would be used as the explanatory variable in the third stage of the CDM model by calculating the expected value after the estimation. Two dependent variables were used in the last stage of the CDM model estimation. One is per-employee sales, which is used as proxy for the growth of the company. The other variable is value added per employee, labor productivity, calculated as the sum of labor cost and operating profit over the number of employees. This is used as a proxy for the profitability of the firm. The log transformed values of both variables were used in the actual analysis.

2) Independent Variables

The explanatory variables used in each stage are classified as follows for the CDM analysis to examine the impact of R&D investment on corporate growth and profitability.

The type of enterprise includes information on whether or not a company was designated as a particular business group as of the end of 2015. Venture or Innobiz-designated firms are noted with respective dummy variables. KOSPI and KOSDAQ listings are also noted with dummy variables.

KIS has information on major customers in the form of dummy variables for three years from 2013 to 2015. These variables distinguish between customers in the public, private, and foreign sectors. In addition, I tried to show which firms engaged in subcontracting business by including a dummy variable containing this kind of information.

As a proxy for the size of the firm, the log-transformed value of the company's sales in 2015 is included as an explanatory variable. Likewise, the log-transformed value of exports in 2015 is also included as an independent variable.

The variables of corporate R&D status are as follows. The master variable indicates the percentage of the workforce with a master's degree or higher among the full-time workforce, while R&D workforce represents the percentage of the full-time workers whose job description reflects dedicated R&D duties. These two values are the ratio values based on 2015 status. In addition, the R&D institute and R&D dedicated department variables that describe the subjects that conduct R&D are dummy variables indicating the existence of an R&D organization within the enterprise. Lastly, I include the proportion of research expenses that are for cooperative research and development (joint and commissioned R&D) among the R&D investment costs based on 2015.

This paper includes independent variables that contains information on process, organization, and marketing innovation, and not only product innovation. First, the number of process innovations refers to the number of types of process innovations introduced by firms in actual R&D operations. The types of process R&D are related to production methodology, logistics, delivery and distribution improvement and other supporting activities. Therefore, this value can have an integer of 0 to 3 as a variable. The first process innovation variable is an independent variable that takes as a dummy variable indicating whether or not the company has a history of process innovation which has been adopted ahead of their domestic or overseas competitors.

Organizational and marketing innovation variables are independent variables that take organizational innovation and marketing innovation as dummy variables. Organizational innovations are introduced through changes in business operation (supply chain management, 6 sigma, knowledge management, and so on), business flexibility, integration between departments (organizational change, education and training systems, and so on) and changes in relations with external organizations (affiliate partners, outsourcing, and so on.) If at least one of these three organizational innovation types is introduced, the dummy variable has a value of 1; it is 0 otherwise. Marketing innovations have four types of innovations. Design or packaging changes in service products, launching of new brands or new advertising/promotion strategies, utilization of new sales strategies (such as introduction of new sales channels) and introducing new pricing systems (discounts and/or price differentiation) are marketing innovations. If at least one of these four marketing innovations is introduced, this dummy variable has a value of 1 and 0 otherwise.

The patent category variables include two kinds of dummy variables. The patent variable represents patent applications filed in the three-year period from 2013 to 2015. The other dummy variable indicates whether other additional trademarks exist or not, such as utility model rights, design rights applications and registration rights.

There are two dummy variables for procurement. First, the contract inclusion variable denotes the existence of a procurement supply contract required the execution of innovation activity. The non-contract variable is a dummy variable indicating that there is a procurement provision contract but no innovation activity included in the contract. Compared to each of these, the reference groups are those firms that have not contracted to perform procurement supply.

The impact of the government support system on corporate performance is very important in terms of considering government policies. KIS includes a questionnaire that assesses whether companies had used government support systems between 2013 and 2015 and how important they are. There are seven kinds of government support system described in the questionnaire: tax, funding, financing, human resources, technology, certification, and procurement support. Companies are required to rank the importance of these support measures by choosing among the following: high, medium, low, and not-used/not-important. In this paper, it is judged that the support system is effectively used only for the companies whose chose medium or high. Only in this case, a value of 1 is assigned to the corresponding government support dummy variables. The procurement support variable is excluded because another questionnaire deals with procurement information.

4. Estimation Results

(1) 1st and 2nd Stage of CDM Model

〈Table 1〉 and 〈Table 2〉 show the estimation results of the CDM model for South Korean service firms surveyed in KIS 2016. 〈Table 1〉 shows the results of the first stage of the CDM model, where the determining the amount of R&D investment is estimated. In the second stage of the CDM model, the estimation of innovation sales per employee, that is, the performance of primary innovation, includes the expected value of the innovation investment estimated in the first stage as an independent variable. The results of 〈Table 1〉 show that the estimated IMR (inverse Mill's ratio) is negative and statistically significant. In other words, the model has a problem of sample selection bias, which is corrected for. In addition, the amount of innovation investment (per employee) showed a positive effect on sales by innovation (per employee).

The results of the government support system excluding procurement showed significant results in terms of tax and human resource support variables. The firms that received tax support were more likely to participate in innovation but the size of innovation investment (per employee) was relatively smaller and the contribution of R&D investment to sales was not significant. These results show that the firms that utilize the tax support system are more likely to carry out innovation activities, but that innovation investment is not vigorous and their effect on R&D performance is ambiguous. The results of human resources support, including labor force, recruitment support, employment referral and training, and the establishment of supporting centers, showed no significant effect on innovation investment decisions (per employee). In other words, there is no difference in the determination of innovation activities between companies that

Table 1. Estimation Results 1st and 2nd Stages of CDM Model

Variable		Innovation		Innovation investment (per employee)		Innovation sales (per employee)	
		estimates	s.e	estimates	s.e	estimates	s.e
Inverse Mill's ratio						-2.73***	1.032
R&D investment per employee						2.13***	0.344
Type of enterprise	Venture	0.629***	0.176	0.380**	0.161	-1.00***	0.319
	Innobiz	0.656***	0.153	0.294**	0.146	-0.838***	0.291
	KOSPI	0.114	0.128	0.223	0.148	-0.755***	0.228
	KOSDAQ	0.762***	0.158	0.279**	0.129	-1.22***	0.287
Demand	Public	-0.110	0.106	-0.191	0.158	-0.736***	0.227
	Private	-0.351***	0.0529	-0.165	0.102	0.325**	0.145
	Foreign	0.0461	0.213	-0.0363	0.212	0.195	0.353
	Subcontract	-0.526***	0.0863	-0.424**	0.185	0.570**	0.271
Sales and Export	Sales	0.112***	0.00975	-0.0617***	0.0153	0.122***	0.0290
	Export	0.0524***	0.0103	0.0260**	0.0114	-0.0814***	0.0208
R&D	Master			0.00769*	0.00396	-0.0145**	0.00583
	R&D workforce			0.0224***	0.00314	-0.0237***	0.00669
	Institute			0.326***	0.110	0.501**	0.223
	Department			-0.0505	0.115	0.491***	0.163
	Cooperation					0.00567	0.00865
Innovations (excluding Product Innovation)	#Process					0.0195	0.0693
	First process					0.885	0.568
	Organizational	0.561***	0.0521	0.144*	0.0814	-1.08***	0.146
	Marketing	0.555***	0.0500	-0.172**	0.0809	0.336**	0.132
Patent	Patent					-0.00659	0.00697
	Other rights					0.171	0.404
Procurement	Contract	0.661***	0.222	0.199	0.192	-0.0336	0.414
	Non-contract	0.196	0.131	0.246	0.177	-0.357	0.244
Government support	Tax	0.533***	0.0893	-0.311**	0.127	-0.325	0.202
	Funds	0.0660	0.0861	-0.0945	0.125	0.0759	0.145
	Finance	-0.165	0.116	0.194	0.151	0.187	0.241
	Human resources	0.0324	0.0837	0.114	0.128	0.472***	0.168
	Technology	-0.206	0.162	0.0223	0.204	0.240	0.288
	Certification	-0.0731	0.142	-0.121	0.177	-0.160	0.240
Cons.		-1.72***	0.0980	1.24***	0.174	0.268	0.291
Obs.		4,000		4,000		1,732	
R^2						0.231	

Note: *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 2. Estimation Results of Final (3rd) Stage of CDM Model

Variable		Sales (per employee)		Value added (per employee)		Value added, Tobit (per employee)	
		estimates	s.e	estimates	s.e	estimates	s.e
Innovation sales (per employee)		0.141**	0.0662	0.294	0.233	0.375	0.257
Type of enterprise	Venture	0.128	0.0967	0.0630	0.168	0.0782	0.176
	Innobiz	0.0902	0.0719	−0.168	0.188	−0.160	0.197
	KOSPI	−0.223***	0.0785	−0.0709	0.164	−0.0842	0.172
	KOSDAQ	−0.0532	0.0721	0.159	0.129	0.171	0.134
Demand	Public	−0.0144	0.117	0.102	0.333	0.206	0.362
	Private	−0.145**	0.0565	−0.00183	0.140	0.0154	0.146
	Foreign	0.172	0.128	−0.253	0.245	−0.323	0.276
	Subcontract	−0.00100	0.102	0.385	0.282	0.444	0.297
Sales and Export	Sales	0.468***	0.0108	0.250***	0.0417	0.258***	0.0443
	Export	0.0120*	0.00622	−0.00686	0.0108	−0.00878	0.0112
R&D	Master	0.00216	0.00216	−0.00170	0.00561	−0.00286	0.00606
	R&D workforce	0.00885***	0.00209	−0.00344	0.00659	−0.00553	0.00724
	Institute	−0.361***	0.0985	−0.378	0.286	−0.449	0.311
	Department	−0.117	0.0736	−0.107	0.164	−0.130	0.173
	Cooperation	−0.00173	0.00239	−0.00408	0.00656	−0.00392	0.00667
Innovations (excluding Product Innovation)	#Process	−0.0619**	0.0292	−0.0640	0.0619	−0.0653	0.0650
	First process	−0.233	0.551	−0.387	0.293	−0.442	0.319
	Organizational	−0.144***	0.0496	−0.00133	0.128	0.0218	0.135
	Marketing	0.0946	0.0597	0.223	0.161	0.197	0.170
Patent	Patent	−0.00287	0.00253	−0.00928	0.00600	−0.0104	0.00735
	Other rights	0.0676	0.122	−0.498	0.347	−0.545	0.374
Procurement	Contract	−0.281*	0.149	−0.857**	0.378	−0.993**	0.411
	Non−contract	0.0723	0.0831	−0.153	0.168	−0.170	0.176
Government support	Tax	0.0654	0.0738	0.0669	0.203	0.116	0.219
	Funds	−0.121**	0.0590	0.0145	0.126	0.0315	0.130
	Finance	−0.0386	0.0826	0.0495	0.230	0.0253	0.243
	Human resources	−0.0672	0.0789	−0.207	0.240	−0.280	0.260
	Technology	−0.0801	0.0982	−0.308	0.229	−0.348	0.249
	Certification	0.0588	0.0894	0.218	0.214	0.251	0.229
Cons.			0.0817	0.542	0.396	0.351	0.428
Obs.				877		877	
R^2				0.136			

Note: *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

receive human resources support from the government and those that do not. However, it can be seen that sales of innovations are relatively higher for companies that have received human resources support.

Overall, patents and procurement did not yield significant results on innovation investment decisions and on revenue from innovation. However, the probability of participation in innovation was higher for cases that included procurement contracts. What is notable is that even the contracted procurement did not affect innovation investment or innovation sales per employee.

(2) Final (3rd) Stage of CDM Model

The third stage of the CDM model looks at the effect of sales by innovative product (per worker) estimated through previous steps, that is, the primary effect of innovation investment on a firm's productivity. This is a very important process to ensure that R&D investment has achieved its final objective. In this stage, the firm's sales (per worker), which represents the growth of the company, and labor productivity, which represents profitability, are adopted as dependent variables. In addition, the labor productivity estimated with the Tobit reflects the fact that a negative value is assignable, unlike the sales amount.

Innovation sales, which is the primary outcome of innovation investment, had explanatory power on firm's sales, but did not have a significant explanatory power on profitability, that is, labor productivity. These results are very important given that the purpose of innovation is not only to grow the company but also to improve profitability. It is more remarkable when we compare the result with previous studies from other countries showing that R&D investment in the service industry positively affects productivity.

Estimation results of the government support measures except for procurement show that fund-aided companies have lower growth and the other variables have no significant effect on the growth and profitability of the corporation. The variables related to patents did not affect growth and profitability of firms, either. In the case of procurement, growth and profitability of firms which had contract-included innovation activities were relatively lower.

5. Policy Implications

The most important results of this paper's quantitative analysis is summarized as follows. Innovation investment at service companies is a significant explanatory variable of primary R&D performance (sales by innovation), and it has also explanatory power in determining corporate growth (sales per employee). However R&D investment failed to explain differences in labor productivity statistically. The most noteworthy result is that in the case of the South Korean service industry, the R&D

mechanisms described by the CDM model in which innovation investment leads to productivity increase are not working.

These results suggest the following policy implications for South Korean service sector's effectiveness in terms of government-supported R&D and private R&D, respectively. First, government-supported R&D should be more efficient. In this case, the biggest problem is not the amount of R&D investment but the disconnection between R&D achievement and service commercialization. It is necessary to develop policies that aim to mitigate regulations and forge links between R&D achievements and commercialization. For example, it is desirable to pursue policies that expand the participation of companies that can actually commercialize R&D results from the R&D planning stage.

Secondly, for the private sector, it is necessary to boost R&D investment, which is relatively low compared to the U.S. and UK.[11) In this perspective, the South Korean government needs a policy that allows service companies to voluntarily promote investment in R&D.

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11) These two countries are the most advanced countries in the development of the service industries.