Governmental Funded Research Programs and Their Determinant: Focus on Matching Fund of Private Sector in Korea

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Abstract--**This research analyzes the performance factors of industrial R&D programs in the relationship between R&D input variables (i.e., budget size and time, firm size, R&D commitment, technology characteristics) and output variables (i.e., patent, paper and technology transfer and realty income). Our results indicate that firm size has positive impact on R&D performances. Technology characteristics is insignificant to all R&D performance factors. However, matching fund ratio is partially significant to most of R&D performance factors, but no moderating effects except firm size.**

I. INTRODUCTION

As technology is becoming more complex, expensive, and faster, the importance of open innovation is increasing. Open innovation is a paradigm which describes the phenomenon collaborating with outside partners in various ways as a process of technology innovation [4]. Since 1980s, cooperative agreement in R&D has been increased in OECD countries. The share of patent co-applications in triad patent families has almost doubled [13]. Moreover, international co-applications in patents are increasing worldwide from 6.5% in 1999 to 8.4% in 2011. Thus, it is important to examine the impact of collaboration in R&D and understand the underlying principles of making partnerships.

Total amount of R&D expenditure of Korea is 6th in the world, and the ratio of R&D expenditure on GDP is 4.15% which is the first in the world in 2013 [10]. Despite of the increase in the investment, the extent of collaboration seems to be low. According to IMD report, the extent of knowledge transfer between firms and universities is consistently decreased by 2007 and ranked in 27th among 60 countries in 2013.

The rate of technology transfer between universities and firms is about 19.5% which is almost half of U.S. Moreover, the extent of technology collaboration between firms is ranked in 37th place. This paper is intended to examine R&D collaboration in Korean public R&D. The ratio of collaboration in public R&D projects in Korea has been increasing continuously and is now about 70%.

Even though the huge government R&D investment, R&D performance is not good. The technology gap is becoming bigger with Korea. It looks like nut cracker between developed country and China [17].

This paper focuses on cooperation R&D in Korea and examines the factors affecting R&D performance.

II. LITERATURE REVIEW

Previous researches about R&D collaboration have been conducted in many different aspects. There were many studies focusing on the impact of R&D collaboration in terms of types of collaboration partnership [2]. Some research has shown that certain combination of partnership may produce better outcomes [18]. Also, domain of technology affects the output of R&D collaboration, since transaction costs of interdisciplinary collaboration are higher than disciplinary collaborations due to the respective party's cognitive difference [8]. Another stream of previous studies on Inter-firm collaboration dealt with factors affecting the impact of on the R&D performance in terms of firm's capacity such as size, number of employees, R&D expenditure, and absorption capacity. Also, other researchers focused on frequency of interaction [7], ratio of research time [15], and communicational factors [2]. All these research, however, focused on the impact of R&D collaboration without uncovering underlying principles of R&D collaborations based on theoretical background.

III. HYPOTHESIS DEVELOPMENT

A. Cooperative R&D and R&D Performance

Under Resource-based view, access to external complementary resources may be necessary to fully exploit the existing resources and develop sustained competitive advantages [20].

Firms and PROs (Public Research Organizations) try to use their resource jointly for saving R&D cost and Risk, so they can get innovation capabilities [6, 9, 11]. Government also has been encouraging technology alliances through R&D cooperation. Therefore, this research establishes the positive impact of joint research capabilities of PROs and firm's commercialization capabilities to R&D performances [6, 11].

Hypothesis one (H1). Projects with R&D cooperation achieves higher R&D performance than projects done alone

B. Firm Size and R&D Performance

One of the advantages of cooperative R&D is the availability of superior and complementary external resources, which is particularly important for SMEs [5]. SMEs may choose to cooperate with external R&D partners to overcome their limited R&D resources.

However, the relationship between firm size and R&D cooperation is ambiguous. In some point SMEs can accomplish superior R&D performance (Schumpeter Mark I). In the other point, large firms can accomplish better R&D performance (Schumpeter Mark II) [5,16]. According to field interview, large companies have enough resources and technology capability for self R&D, and they hesitate to join government R&D due to the administrative burden and technology disclosure policy.

SMEs is likely to get and commercialize new technologies which are transferred from public research organizations after R&D cooperation with them. Therefore, this research establishes the following hypothesis.

H2. Firm size has an influence on the R&D performance.

H2-1. Projects conducted by SMEs have a higher R&D performance than projects done by large companies.

C. TRL and R&D Performance

Korea government is using Technology Readiness Levels (TRL) which is a type of measurement system to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest. When a technology is at TRL 1, scientific research is beginning and those results are being translated into future research and development. TRL 2 occurs once the basic principles have been studied and practical applications can be applied to those initial findings. TRL 2 technology is very speculative, as there is little to no experimental proof of concept for the technology [19].

Firms try to get and protect their IP right and then go into commercialization by using the IP. It means that the firms have a merit to join R&D projects which are targeted more higher TRL. And PROs also have an incentive to do a cooperation research with firms, because they can transfer the technologies to industrial sectors and also expect royalty income. Thus, Therefore, this research suggests the following hypothesis.

H3. Projects with higher TRL are expected to more R&D performance than projects with lower TRL

D. R&D Commitment & R&D performance

Cooperative R&D requires a high level of commitment by partners involved in projects. Previous studies show that the higher the degree of participation and involvement of the partners and of the senior executives, the more effective the cooperative relationship will be.

Commitment usually measured by emotional commitment, prospects of continuity, the wish to invest, frequency and content of the communication and the investment made in specific assets as a result of the agreement

There are few R&D projects that subsidized 100% R&D budget by government. Almost matching fund scheme (ex, government R&D budget 70% : Private firms 30%). Matching fund policy has an influence to firm's attitude to R&D projects. Thus, the more investment in R&D, the more commitment (decreasing moral hazard) [1]. And, R&D commitment and responsibility is proportional with R&D investment. Therefore, this research proposes the following two hypotheses.

H4. More commitment has a positive influence on the R&D performance.

H5. R&D Commitment moderate the R&D performance on the firm size, TRL and number of participants

In summary, this research establishes the relation between R&D performances and their characteristics with the five hypotheses in **Figure 1.**

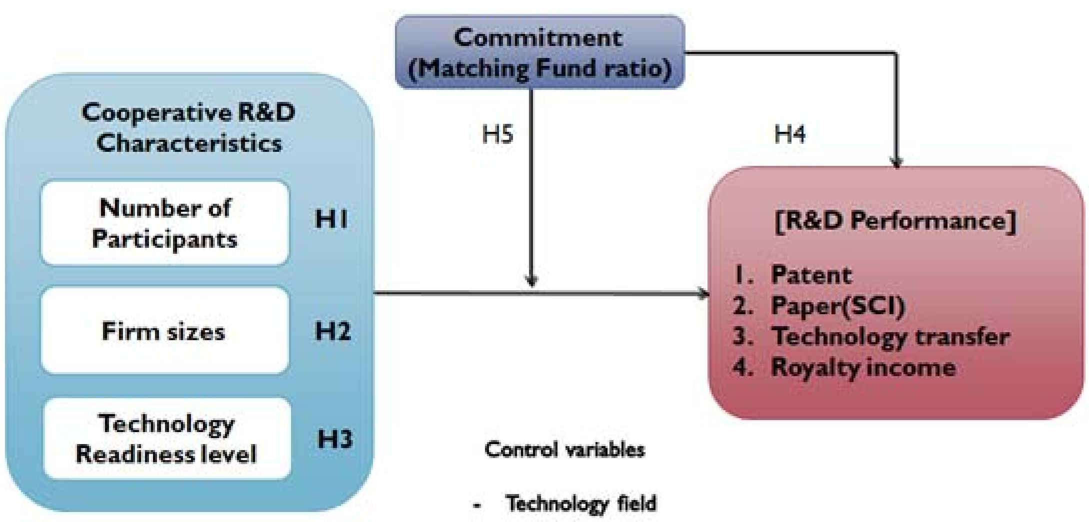

Figure 1. Analytic framework of this research

IV. SAMPLE DATA AND METHODOLOGY

A. Sample

This research utilized the dataset of R&D project inputs and outputs from Korea Evaluation Institution of Industrial Technology (KEIT). The project had implemented from 2009 to 2013 (5 years) with the financial support and the administrational monitoring of KEIT. This study settled the final dataset of 1,248 projects which a private firm(s) had managed during the project period.

B. Variables

This research established four dependent variables and six independent variables (**Table 1**). Four dependent variables are the project performances of number of patent, papers published in SCI journals, technological transfer (TRL), royalty incentive (unit: billion South Korean Won(KRW)). Six independent variables are the number of employees, the months of a project, government investment (unit: billion KRW), matching fund ratio of private sector (MRP), participating organizations, the degrees of technological transfer (from 1 to 5 with commercial development). This study measured the MRP as the proportion of a private sector's investment and goods divided by total budget of a project.

C. Methodology: Poisson regression

This research investigated the correlation among dependent variables (**Table 2**) and the association among independent variables (**Table 3**). All values of mean variance inflation factor (VIF) is lower than 10, which implies no serious multi-collinearity among (in) dependent variables. The sample has several variables with heterogeneity of residuals and this study utilized Poisson regression with count data (e.g., patent, journal papers) instead of adopting ordinary least square.

V. RESULTS

Table 4 to 7 shows that government R&D investment and project period positively contribute to R&D performance. Also, large firms are likely to achieve more R&D performance than SMEs, which is the opposite result to H2. And then, R&D cooperation is stronger contributor to the commercialization performance (technology transfer and royalty income) than the patent or the paper. However, TRL is no significant to all R&D performance, which does not support H3. Finally, MRP is partially significant to most of R&D performance factors (patent, paper and royalty). On moderating effect of MRP, MRP has only the positive moderating effect to firm size, which partially supports H5.

TABLE 1. DESCRIPTIVE STATISTICS

Definition	Unit, Scope	Variable	Observations	Mean	Standard deviation
Patent	Positive integer	pat	1,248	1.6	3.8
SCI papers	Positive integer	sci	1,248	0.9	10.0
Tech transfer	Positive integer	techt	1,248	0.2	0.4
Royalty incentive	Billion KRW	roy13	1,248	33.1	104.6
Employee	Person	maj_emp	1,248	723.9	3269.6
Periods of a project	Month	cmon	1,248	34.1	21.5
Governmental investment	Billion KRW	gov_cap	1,248	1.5	1.6
MRP	Ratio: [0,1]	np_mat	1,248	0.3	0.1
Number of participating organizations	Positive integer	npar	1,248	3.0	2.2
TRL level	Ordered dummy: [1,5]	cat_trl5	1,248	3.5	0.9

Notes. Matching fund ratio of private sector (MRP). Technological transfer (TRL). TRL level confers to one (basic technology transfer), two (feasible research), three (technology development), four (technology demonstration), and five (system developmet).

TABLE 2. CORRELATION MATRIX OF DEPENDENT VARIABLES

	pat	sci	techt	roy13
pat	1			
sci	0.030	1		
techt	-0.049	-0.011	1	
roy13	0.058	0.019	0.561	1
mean VIF	1.310	1.460	1.000	

TABLE 3. CORRELATION MATRIX OF INDEPENDENT VARIABLES

	cat_trl5	maj_emp	cmon	gov_cap	np_mat	npar
cat_trl5	1					
maj_emp	0.044	1				
cmon	0.076	0.145	1			
gov_cap	0.141	0.310	0.544	1		
np_mat	0.121	0.276	0.328	0.282	1	
npar	0.157	0.214	0.173	0.574	0.099	1
mean VIF	1.550	1.610	1.400	1.010	1.000	

TABLE 4. RELATIONSHIP BETWEEN PATENT AND INDEPENDENT VARIABLES

Patents	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
cat_trl5	**0.274**	**0.001**	**0.271**	**0.001**	**0.266**	**0.001**	0.348	0.207	**0.273**	**0.001**	**0.259**	**0.002**
maj_emp	0.000	0.197	**0.000**	**0.003**	0.000	0.252	0.000	0.201	0.000	0.202	0.000	0.330
cmon	**0.018**	**0.000**	**0.018**	**0.000**	**0.017**	**0.000**	**0.018**	**0.000**	**0.018**	**0.002**	**0.015**	**0.000**
gov_cap	**0.110**	**0.006**	**0.114**	**0.005**	**0.123**	**0.006**	**0.111**	**0.006**	**0.110**	**0.006**	**0.472**	**0.000**
np_mat	**2.744**	**0.000**	**2.997**	**0.000**	**3.478**	**0.000**	3.454	0.139	**2.833**	**0.002**	**4.761**	**0.000**
npar	0.033	0.254	0.034	0.228	0.114	0.136	0.032	0.273	0.032	0.258	0.023	0.428
constant	-2.542	0.000	-2.635	0.000	-2.782	0.000	-2.815	0.004	-2.570	0.000	-3.165	0.000
maj*np_m			**0.000**	**0.012**								
par*np_m					-0.220	0.368						
cat*np_m							-0.190	0.775				
cmon*np_m									-0.002	0.925		
gov*np_m											**-0.821**	**0.000**
obs	1,248		1,248		1,248		1,248		1,248		1,248	
Wald chi(6,7)	160.700	0.000	175.020	0.000	178.590	0.000	162.090	0.000	216.870	0.000	214.550	0.000
Pseudo R2	0.173		0.179		0.174		0.173		0.173		0.185	

TABLE 5. RELATIONSHIP BETWEEN SCI PAPER AND INDEPENDENT VARIABLES

SCI papers	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
cat_trl5	0.010	0.935	0.010	0.932	-0.010	0.935	-0.246	0.621	0.024	0.843	-0.115	0.452
maj_emp	0.000	0.155	0.000	0.774	0.000	0.214	0.000	0.194	0.000	0.168	0.000	0.865
cmon	**0.035**	**0.000**	**0.035**	**0.000**	**0.034**	**0.000**	**0.035**	**0.000**	**0.051**	**0.000**	**0.027**	**0.000**
gov_cap	**0.395**	**0.015**	**0.397**	**0.014**	**0.415**	**0.019**	**0.401**	**0.021**	**0.378**	**0.014**	**1.330**	**0.001**
np_mat	-2.674	0.214	-2.589	0.235	-1.496	0.385	-5.208	0.406	1.356	0.569	**6.163**	**0.005**
npar	-0.060	0.540	-0.059	0.543	0.064	0.530	-0.057	0.542	-0.066	0.508	-0.095	0.289
constant	-1.791	0.017	-1.834	0.017	-2.093	0.004	-0.935	0.636	-3.023	0.000	-4.284	0.000
maj*np_m			0.000	0.405								
par*np_m					-0.397	0.340						
cat*np_m							0.745	0.578				
cmon*np_m									**-0.053**	**0.051**		
gov*np_m											**-2.342**	**0.002**
obs	1,248		1,248		1,248		1,248		1,248		1,248	
Wald chi(6,7)	135.200	0.000	136.180	0.000	146.370	0.000	157.980	0.000	127.170	0.000	105.430	0.000
Pseudo R2	0.412		0.412		0.413		0.413		0.417		0.485	

TABLE 6. RELATIONSHIP BETWEEN TECHNOLOGY TRANSFER AND INDEPENDENT VARIABLES

Tech transfer	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
cat_trl5	-0.040	0.439	-0.044	0.396	-0.053	0.314	0.189	0.158	-0.041	0.428	-0.055	0.291
maj_emp	0.000	0.191	**0.000**	**0.039**	0.000	0.280	0.000	0.211	0.000	0.202	0.000	0.292
cmon	**0.004**	**0.081**	**0.004**	**0.093**	0.003	0.204	**0.004**	**0.091**	0.006	0.231	0.002	0.455
gov_cap	**0.079**	**0.040**	**0.083**	**0.031**	**0.097**	**0.012**	**0.079**	**0.039**	**0.078**	**0.042**	**0.303**	**0.000**
np_mat	-0.443	0.342	-0.158	0.733	0.599	0.360	1.965	0.143	-0.168	0.814	0.716	0.213
npar	0.029	0.258	0.028	0.258	**0.139**	**0.027**	0.026	0.309	0.028	0.266	0.022	0.382
constant	-1.487	0.000	-1.561	0.000	-1.760	0.000	-2.246	0.000	-1.560	0.000	-1.748	0.000
maj*np_m			**0.000**	**0.048**								
par*np_m					**-0.353**	**0.065**						
cat*np_m							-0.713	0.071				
cmon*np_m									-0.006	0.666		
gov*np_m											**-0.578**	**0.008**
obs	1,248		1,248		1,248		1,248		1,248		1,248	
Wald chi(6,7)	25.920	0.000	29.620	0.000	31.380	0.000	28.810	0.000	26.230	0.001	38.850	0.000
Pseudo R2	0.011		0.014		0.013		0.013		0.011		0.014	

TABLE 7. RELATIONSHIP BETWEEN ROYALTY INCOME AND INDEPENDENT VARIABLES

Royalty	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
cat_trl5	0.048	0.581	0.048	0.582	0.022	0.808	0.343	0.142	0.047	0.591	-0.004	0.968
maj_emp	0.000	0.295	**0.000**	**0.008**	0.000	0.565	0.000	0.332	0.000	0.320	0.000	0.843
cmon	**0.015**	**0.000**	**0.015**	**0.000**	**0.013**	**0.000**	**0.015**	**0.000**	**0.021**	**0.001**	**0.008**	**0.009**
gov_cap	**0.160**	**0.004**	**0.174**	**0.003**	**0.195**	**0.001**	**0.158**	**0.004**	**0.157**	**0.004**	**0.748**	**0.000**
np_mat	0.167	0.840	0.567	0.471	**2.550**	**0.032**	3.093	0.211	1.163	0.378	**4.265**	**0.000**
npar	**0.123**	**0.002**	**0.122**	**0.002**	**0.319**	**0.003**	**0.121**	**0.002**	**0.122**	**0.002**	**0.099**	**0.017**
constant	1.909	0.000	1.752	0.000	1.212	0.006	0.863	0.276	1.619	0.001	0.816	0.043
maj*np_m			**0.000**	**0.028**								
par*np_m					-0.599	0.102						
cat*np_m							-0.820	0.255				
cmon*np_m									-0.019	0.306		
gov*np_m											**-1.395**	**0.000**
obs	1,248		1,248		1,248		1,248		1,248		1,248	
Wald chi(6,7)	152.240	0.000	178.280	0.000	165.760	0.000	167.170	0.000	168.780	0.000	185.960	0.000
Pseudo R2	0.171		0.181		0.183		0.173		0.171		0.213	

VI. CONCLUSION

This research suggests several policy implications for a government to management its industrial R&D project. Above, matching fund policy seems to be productive tool to improve R&D performance. However, technology characteristics does not have significant contribution to the performance, which seems to be the project participants or researchers' role. Although many government tries to support investment in small and medium enterprises (SME), our result suggests different stories that big companies acquire more R&D performance than SMEs. Therefore, this research proposes the management and restructure of SME oriented R&D policies for project productivity.

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