Analysis of Performance-Improving Factors of International R&D Collaborations Conducted by Universities in South Korea

Sang Hyon Lee*[1], Hayoung Cho[1], Daeryeok Lee[2]

Abstract

Hence the recent global R&D trend towards large-scale, interdisciplinary co-work and technological development within a single country or company has been becoming increasingly difficult. The world has become a single enormous market, as in the case of the patent dispute between Apple and Samsung, and, consequently, there is intense competition in the field of new technology development.

In view of these changes, South Korea, along with other major developed countries, is emphasizing the need for international R&D collaboration on S&T policy. However, recent OECD reports show that the indices related to the S&T internationalization of South Korea have remained at a low level compared to the OECD average. Therefore, constant efforts to enhance S&T globalization and the performance of international R&D collaboration are necessary in South Korea.

In this study, given that in South Korean universities not only conduct most international collaborations with government-funded R&D projects (74.6%) but also train and produce high-quality R&D manpower, an analysis was conducted on the performance-creating factors for international collaboration on government-funded R&D projects conducted by universities based on such outputs as papers and patents, as well as on the performance-improving factors concerning output-produced international R&D collaborations. In conclusion, implications for performance enhancement were suggested through a comparison of these factors with those discussed in previous studies.

On the other hand, a survey of research outputs other than papers and patents, and performance-influencing factors used by researchers with experience of international collaboration in the R&D field, was conducted and the results analyzed. As a result, additional performance evaluating indicators were also suggested to be considered for performance enhancement, because they were thought to connote the practical characteristics of international R&D collaboration.

Keywords: Performance-improving Factor, International R&D Collaboration, Universities

1. Introduction

Due to the ever increasing trend towards the development of large-scale interdisciplinary sciences and technologies (S&T), technological development by a single nation or company is becoming increasingly difficult. Accordingly, the world has become a huge single market, and the struggle for technology development is becoming fiercer, as can be seen in the recent dispute between Samsung and Apple over patents. Amid such environmental changes, the S&T paradigm is changing from one of closed-type R&D to one of shared-type technology R&D involving joint R&D between nations and R&D collaboration networks

[1] *Korea Institute of S&T Evaluation and Planning(KISTEP), 9F Dongwon Bldg, 68 Mabang-gil, Seocho-gu, Seoul 137-130, Korea*
[2] *Korea Institute of Marine S&T Promotion(KIMST), Samho Company LTD. B-Bldg. Yangjae 2-Dong, Seocho-Ku, Seoul 137-941, Korea*
* Corresponding author: shlee@kistep.re.kr

between various institutes (Hong, 2010).

With these changes in the S&T paradigm, major nations are emphasizing the need to bolster international R&D collaboration in their S&T policies, and South Korea has formulated and is pushing ahead with national policies for S&T internationalization and the activation of international R&D collaboration. However, given the recent report that South Korea's S&T internationalization is at the lowest level among the OECD member nations, its S&T globalization level needs to be enhanced (NSTC, 2011).

In fact, as shown in Table 1, of all the South Korean government's R&D projects, international collaboration projects numbered just 1,308 (366.12 USD million) in 2011, accounting for only 3.1% (2.8%) of the grand total of 41,619 projects (12,906.16 USD million). The rate of increase has remained at a low level since 2008 (around 1%), attesting to the slow progress of international R&D collaboration.

On the other hand, as a result of comparing the research outputs (in terms of paper and patent productivity) of international R&D collaboration and total government-funded R&D projects, it was confirmed that, although the government's R&D projects have not boosted international collaboration significantly, the productivity of international R&D collaboration was far higher than that of the total number of R&D projects, as shown in Table 2. International R&D collaborations produced about one more SCI paper and patent application/registration per research project than the total R&D projects in 2008 and 2009, while the difference declined in 2010. For every one million USD invested in research project budgets, international R&D collaborations produced a higher number of SCI papers and patent applications and registrations than the total R&D projects did, and the difference continued to increase.

An examination of international R&D collaboration by research organization revealed that paper output was higher for universities and government-funded research institutes (GRIs), while patent output was higher for large companies and GRIs, as shown in Table 3. In 2008, the number of papers per project was higher for GRIs, whereas, from 2009, the number

Table 1 Government-funded international R&D collaboration in South Korea

(US million* / No.)

Category	2008		2009		2010		2011	
	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration	Total R&D	Intl. collaboration
Budget (portion)	9,659.02	300.10 (3.1%)	9,279.30	332.12 (3.5%)	11,358.50	385.74 (3.4%)	12,906.16	366.12 (2.8%)
No. of projects (portion)	37,449	1,068 (2.9%)	39,471	1,020 (2.6%)	39,179	1,192 (3.0%)	41,619	1,308 (3.1%)

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ Taken from the government R&D project survey and analysis report (2008~2011)

Table 2 Outputs: total number of R&D projects vs. international R&D collaboration projects

Category	2008		2009		2010	
	Total government R&D	international collaboration	Total government R&D	international collaboration	Total government R&D	international collaboration
No. of papers	17,635	1,517.6	19,519	2,542.4	17,486	1,936.4
(per project)	(0.47)	(1.42)	(0.49)	(2.46)	(0.45)	(1.98)
(per million USD*)	(1.84)	(2.06)	(2.12)	(3.99)	(1.57)	(5.55)
Total number of patents	16,285	1,505.6	14,314	1,750.3	16419	1,214.4
(per project)	(0.43)	(1.41)	(0.36)	(1.69)	(0.42)	(1.24)
(per million USD*)	(1.72)	(2.06)	(1.60)	(2.66)	(1.45)	(3.45)

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ SCI-level papers, i.e. total number of domestic and foreign-registered and filed patents.

Table 3 International R&D collaboration outputs by research organization

Organization	2008			2009			2010		
	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects	Paper (per project) (per million USD*)	Patent (per project) (per million USD*)	No. of projects
National and public research institutes	59.8 (0.62) (2.29)	28.8 (0.3) (1.15)	96	38.2 (1.16) (5.32)	9.8 (0.30) (1.33)	33	5.5 (0.79) (4.34)	3.4 (0.49) (2.65)	7
Large companies	8.3 (0.35) (0.11)	70 (2.92) (1.38)	24	18 (0.55) (0.13)	8 (0.24) (0.13)	33	4.7 (0.36) (0.12)	37 (2.85) (1.09)	13
Universities	798 (1.52) (4.93)	557.6 (1.06) (3.44)	526	1719.6 (3.10) (10.38)	1028.3 (1.85) (6.25)	555	1652.2 (2.27) (8.08)	840.5 (1.15) (4.10)	729
SMEs	3.7 (0.06) (0.23)	59.1 (0.88) (3.33)	67	5.5 (0.06) (0.27)	101.5 (1.07) (3.86)	95	8.9 (0.12) (0.36)	86.6 (1.15) (3.62)	75
GRIs	608.9 (1.89) (1.38)	762.1 (2.36) (1.72)	323	707.6 (2.47) (2.26)	574.2 (2.00) (1.73)	287	259.6 (1.94) (3.86)	230.7 (1.72) (3.38)	134
Others	38.9 (1.50) (1.15)	28 (1.08) (0.80)	26	53.5 (2.33) (2.53)	28.5 (1.24) (1.33)	23	5.5 (0.31) (0.36)	16.2 (0.9) (1.21)	18
No. of output-reported projects*	-	-	1,062	-	-	1,026	-	-	976

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)
※ Non-reported outputs were excluded, causing a statistical difference.

was highest for universities, which also had a higher number of patent applications and registrations. Also, the number of papers and patents per million USD for universities were considerably higher than that for any other organization from 2008 to 2011, suggesting that universities were outstanding in terms of the research outputs obtained from international R&D collaboration.

As seen above, even when the statistics are used for nothing more than a simple inter-group comparison, they suggest that the activation of international R&D collaboration from government R&D projects and the promotion of research performance can be an effective way of enhancing South Korea's S&T globalization. Hence, this study examined the research outputs derived from government R&D projects involving international R&D collaboration in order to analyze and determine the factors which improve performance. In particular, together with the factors which can create performance as regards paper and patent outputs, a number of performance-improving factors were analyzed to determine how research output can be enhanced for projects aiming for paper and patent outputs. Thus, this paper discusses determinants of activation of international R&D collaboration and performance-improving factors in South Korea. Furthermore, in addition to papers and patents, the output and the determinants of such performance, deemed important by researchers, are surveyed to propose performance-evaluating indicators for international R&D collaboration.

2. Target of Analysis : University-conducted International R&D Collaboration

With the aim of analyzing S&T, this study analyzed the details of international R&D collaboration on government R&D projects reported in the NTIS[1)] over three years (2008~2010) up to August 2012, excluding the humanities and social science sectors.

A review of international collaboration research projects by research organization reveals that universities steadily increased their share, as shown in Figure 1, accounting for 74.6% in 2010. This suggests that, to boost their international competitive edge, universities have been pushing ahead with internationalization efforts, and that universities with a shortage of research infrastructures appear to be pursuing international collaboration in order to use overseas infrastructures. On the other hand, the share of other research organizations has declined, suggesting that universities are leading the way in terms of international collaboration.

Participation in international collaboration, based on the entry criteria of the NTIS Survey-Analysis Data, as shown in Table 4, was classified into six types[2)], revealing that collaboration was focused on international agreements and the attraction of foreign researchers, and that a growing number of international agreements and researchers were being sent overseas, while information exchange had declined. Of these, the government's international R&D collaboration projects conducted by universities also involved the attraction of many foreign researchers, the dispatch of a growing number of researchers overseas, and the signing of international agreements, showing a similar trend in the overall participation types.

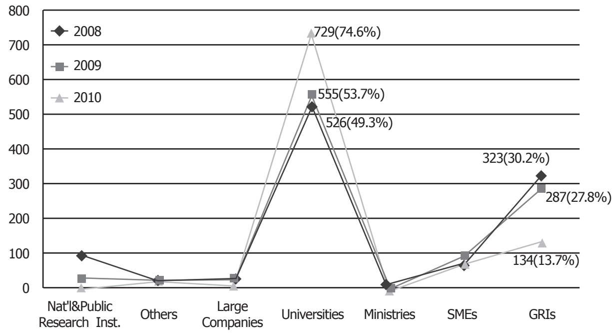


Figure 1 Classification of international collaboration research projects by carrier

Table 4 Number. of international collaborations by participation type

(USD million, no. of cases)

Participation type	2008		2009		2010	
	Total	University conducted	Total	University conducted	Total	University conducted
International agreement	388 (17.3%)	173 (14.5%)	368 (16.4%)	180 (13.5%)	520 (19.9%)	228 (13.9%)
Technical training	54 (2.4%)	31 (2.6%)	63 (2.8%)	30 (2.2%)	39 (1.5%)	33 (2.0%)
Dispatch of researchers overseas	25 (1.1%)	10 (0.8%)	392 (17.5%)	264 (19.8%)	478 (18.3%)	350 (21.4%)
Attraction of foreign researchers	758 (33.7%)	597 (50.0%)	896 (40.0%)	734 (55.0%)	987 (37.8%)	833 (50.9%)
Commissioned project	288 (12.8%)	45 (3.8%)	276 (12.3%)	45 (3.4%)	302 (11.6%)	57 (3.5%)
Information exchanges	735 (32.7%)	337 (28.2%)	247 (11.0%)	81 (6.1%)	283 (10.8%)	136 (8.3%)
Total	2,248	1,193	2,242	1,334	2,609	1,637

* Converted from KRW according to the yearly average exchange rate for the corresponding year (www.irs.org)

1) National Science & Technology Information Service

2) Based on the entry criteria of the 'NTIS Survey-Analysis Data', international collaboration participation types

① International agreements: Concluding international agreements with foreign research institutes for R&D collaboration

② Technical training: Sending domestic researchers to overseas research institutes, etc. for technical training for over 15 days

③ Dispatch of researchers overseas: Dispatch of domestic researchers (including students on masters and Ph.D. courses) to foreign research institutes for joint R&D collaboration for over 3 months.

④ Attraction of foreign researchers: Foreign researchers participating in joint R&D collaboration at domestic institutes, etc.

⑤ Commissioned project: Commissioning of parts of R&D projects to foreign research institutes

⑥ Information exchange: Exchange of information with and seeking advice from foreign research institutes for the purpose of R&D

Thus, this study examined international R&D collaboration by universities which, in carrying out government-funded R&D projects in South Korea, conduct the most international collaborations (74.6%, excluding the humanities and social science sectors), and which produce significant research performances, in a bid to analyze the determinants of performance creation and improvement.

3. Data and Method of Analysis

3.1 Differentiation from Previous Studies

According to general research, performance-creating factors include the size of the project budget, the number and research capabilities of participating researchers, and the research period. According to many studies, in general R&D projects, the size of a project budget is an influential factor, but it may or may not influence performance improvement (Grimaldi & Tunzelmann, 2003; Choe, 2007; Michael Schwartz et al., 2010; Jang, 2010; Kim, 2010; Choe et al., 2011; Ryu, 2011; Kim, 2012). The number of participating researchers may also either influence performance enhancement or not (Grimaldi & Tunzelmann, 2003; Choe, 2007; Kim, 2012), while the research capabilities of the participating researchers, and the research period have effects on performance improvement (Choe, 2007; An, 2009; Choe et al., 2011; Ryu, 2011; Kim, 2011; Gwon, 2012; Kim, 2012).

In simple collaboration research projects, performance-influencing factors such as experience of collaboration on joint technology development, etc., frequency of contact and depth of communication with counterpart institutes, and the level of mutual trust were also studied. Collaboration experience, frequency of contact with counterpart institutes, and the level of mutual trust all had effects on performance improvement (O, 2004; An, 2009; Yang et al., 2010; Kim, 2011), whereas communication had significant effects or no effects at all (O, 2004; Kim, 2004; An, 2009). Regarding corporate business performance, Ryu (2011) revealed that corporate network size has an influence on performance improvement.

On the other hand, very little research has been conducted on performance-improving factors with regard to international R&D collaboration. Choe (2007) revealed that joint research with foreign researchers produces higher productivity compared with single-party research and joint industrial research, while Kim (2010) revealed that the greater the number of overseas network degree, the more positive effect it had on research performance. Kim (2012) also reported that researchers' human networks influence the writing of international joint papers. Regarding corporate performance, Kim (2006) reported that the diversification of overseas network collaboration does not necessarily produce positive results.

In reviewing previous studies on the performance-influencing factors of international R&D collaboration, although based on empirical data, only an analysis of the performance-creating factors was carried out, and this was based only on research organizations or R&D programs, thereby limiting the scope of the research. Thus, this study sets analysis units based on projects, and confirms the performance-improving factors of international collaboration on government-funded R&D projects that produced research outputs, papers or patents.

3.2 Analysis Model

This study aims to confirm the performance-improving factors of international collaborations under government-funded R&D projects. Thus, the analysis model used in this study includes 'frequency of international collaboration,' which was used as a performance-influencing factor in Kim study (2010), and has been modified from 'degree of exchange' and adjusted to research projects for this study. Two further performance-influencing factors, namely 'international collaboration participation type' and 'continuity of international collaboration,' have been added to the analysis model, thus enabling the analysis of research projects.

Also, given that certain research projects were under way, the 'related research year-period,' which was measurable based on the research projects rather than on the total research period, was newly added to the analysis model as a control variable.

The dependent variables are 'research performance', which targets papers and patents derived from S&T performance, as defined Article 2, Section 8 of the Act on Performance Evaluation, and Performance Management of R&D Programs, etc.

A diagram of the analysis model is shown in Figure 2. Logistic regression analysis and multi- regression analysis are used as the analysis methods.

3.3 Gathering of Data

This study analyzed the data of government-funded R&D projects, which were surveyed and analyzed each year by the government, according to the Master Act for S&T - Article 12 (Survey, Analysis and Evaluation of Government R&D Projects). These data are entered into the NTIS system after verification by KISTEP, and provided to the general public.

Such NTIS data (as of August 2012) entered over the past three years (2008-2010) were analyzed, with the limitation to the universities-conducted international collaboration research projects from the government-funded R&D projects.

Of the total of 1,394 such research projects, 1,024 were selected and analyzed, while 319 research projects with unclear research outputs, as well as 51 research projects conducted by research centers and project centers, and those based on the joint use of equipment with large-scale manpower and budget, were excluded so as to avoid any distortion of the statistics (continuous research projects were determined as one project).

As shown in Figure 3, the data showed a skewed distribution, with a pattern showing a high frequency of "0", and a tilt in one direction. Thus, the performance-creating factors and the performance-improving factors were analyzed separately; "0" was included in determining the performance-creating factors, but excluded in determining the performance-improving factors, as explained below in Section 3.4.

3.4 Method of Analysis

To confirm the performance-creating factors, logistic regression analysis, which is effective in identifying useful covariance for the prediction of whether specific events occur, was applied in this study. The dependent variable concerns the creation or non-creation of

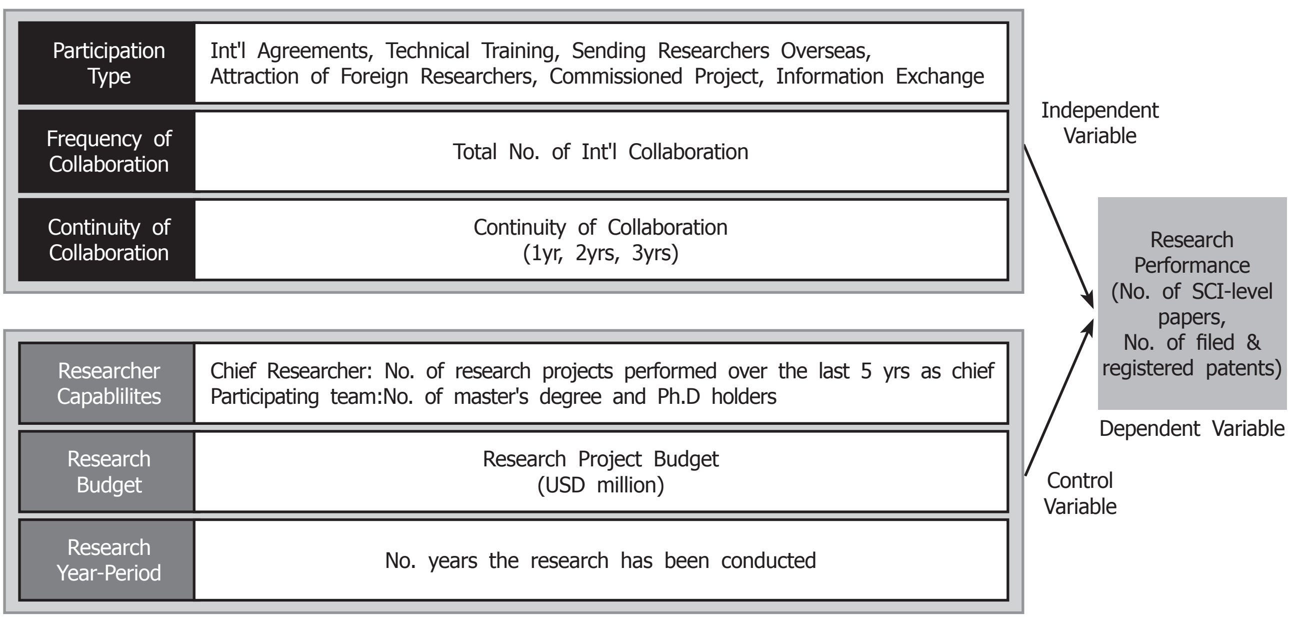


Figure 2 Empirical analysis model

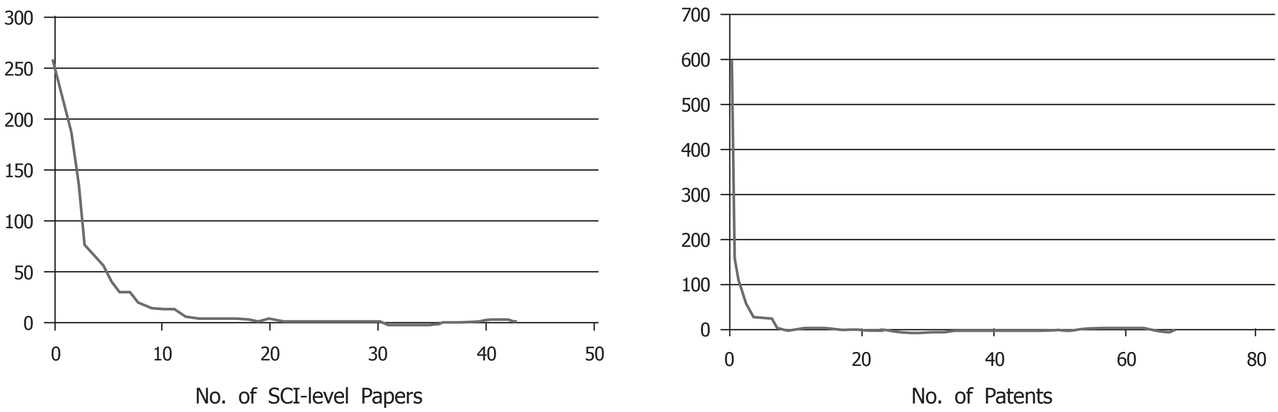


Figure 3 Distribution of research outputs

research outputs, thus allowing the probability concept (p: probability of research output creation) to be applied; and, since there are several independent variables and control variables, the basic regression analysis model was used as per equation 1.

To confirm the performance-improving factors with regard to the research projects that produced research outputs, multi-regression analysis, which is generally used when there are several independent variables influencing the dependent variable of continuous data, was conducted. Since the dependent variable is the research outputs of continuous data and there are several independent variables and control variables, the basic-multi regression analysis model was used as per equation 2. However, since the data showed a skewed distribution, to meet the regression analysis assumption, they were analyzed using the analysis model with the natural logarithm as the dependent variable, as expressed in equation 3.

$$\ln(\frac{p}{1-p}) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (1)$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (2)$$

$$\ln(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (3)$$

3.5 Measurement of Variables

The independent variables include ‘international collaboration participation type’, ‘frequency of collaboration’, and ‘continuity of collaboration’. These data were acquired from the NTIS survey-analysis data related to international research collaboration. International collaboration participation type, as shown in Chapter 2, can be classified into six types, and the number of collaborations carried out for each participation type was measured to analyze the effect of collaboration type on research output. For instance, there could be two cases of technical training and three cases of information exchange conducted within a research project, and such information on each project was arranged into a database. The frequency of international collaboration was determined by adding up the number of the six participation types in each research project. International collaboration continuity was determined by measuring whether the international R&D collaborations were conducted sporadically for a year, or continually over 2~3 years during the 3-year period (2008-2010) considered in this study.

The control variables include ‘research budget’, ‘researcher capabilities’, and ‘research year-period’. These data were acquired from the NTIS survey-analysis data. ‘Research budget size’ was determined by measuring the amount of government funds invested in each research project. Since the chief researcher of a government-funded R&D project is selected by competition, ‘chief researcher’s ability’ was measured according to the number of government R&D projects led by a chief researcher over the past five years. ‘Participating researchers' research ability’ was measured by totaling the number of masters and Ph.D. holders participating in each research project.

'Research year-period' was determined by measuring the number of years into the research since project start, from the point where international collaboration was last conducted. Through examining this, the effect of research project development according to its stage can be analyzed.

The dependent variable, 'research performance', was determined by measuring the number of SCI-level papers published and the number of patent applications and registrations deriving from each research project. 'NTIS data related to research output' reflects the contribution ratio of the related research projects, and therefore is considered as a more appropriate index than the simple number of research outputs.

4. Results of Analysis

4.1 Factors Influencing the Paper Output of International R&D Collaborations

For the multi-regression analysis of the analysis model, PASW Statistics (SPSS) 18 was used, while the Hosmer and Lemeshow test was used to verify the analysis model. This confirmed that, as shown in Table 5, the significance probability was 0.380, which is greater than 0.05, suggesting that the analysis model was suitable. The Negelkerke R2 value, i.e. the explanatory power of the analysis model, as shown in Table 6, was 0.273, suggesting that the analysis model had an explanatory power of 27% regarding the creation of paper outputs.

The regression analysis revealed that, of the control variables, 'research project year-period' and 'chief researcher capability' had a significant effect on paper output, as shown in Table 7. Of the independent variables, the dispatch of researchers overseas had a significant effect on paper output. This suggests that while personal research capabilities are crucial for paper output, research project budget, having an OR (Odds Ratio) of 1.001, would have a small effect on the creation of paper output.

Table 5 Hosmer and Lemeshow test

Stage	Chi-square	Degree of freedom	Significance probability
1	8.572	8	.380

Table 6 Explanation power of the analysis model

Stage	-2 Log likelihood	Cox and Snell R-square	Nagelkerke R-square
1	956.627[2]	.186	.273

Table 7 Results of logistic regression analysis of paper output

	Variables	β*	Significance probability	Exp(B)**
	(Constant)	.086	.915	1.090
Control	Research project year-period	.426	.000	1.531
	Chief researcher capability	.287	.000	1.332
	No. of Masters and Ph.D. holders	-.008	.596	.994
	Research project budget	.001	.029	1.001
Independent	International agreement	0.370	.819	1.038
	Technical training	.191	.515	1.210
	Overseas dispatch	.494	.005	1.639
	Attraction from overseas	.207	.114	1.230
	Commissioned research projects	-.076	.792	.927
	Information exchanges	-.195	.171	.823
	Continuity_2nd year	-.619	.036	.538
	Continuity_3rd year	-.888	.152	.421
	Frequency of collaboration LN	-.201	.572	.818

*Regression coefficient, **Odds ratio(OR)

4.2 Factors Influencing the Patent Output of International R&D Collaborations

The suitability of the analysis model was verified using the Hosmer and Lemeshow test. As shown in Table 8, the significance probability was 0.145, which is greater than 0.05, confirming the suitability of the analysis model. As can be seen in Table 9, the analysis model's explanatory power, namely, Negelkerke R2, was 0.174, indicating that the model has an explanatory power of 17% regarding its ability to identify the creation of patent output.

The regression analysis revealed that, of the control variables, 'chief researcher capabilities' had a significant effect on the creation of patent output, as shown in Table 10. Of the independent variables, 'international agreements' and 'frequency of collaboration' had a positive effect on the creation of patent output. Presumably, international positive collaboration at the institute-level, rather than at the personal-level, can influence the creation of patent output, and the higher the frequency of collaboration, the higher the probability of patent output creation. However, since the various types of international collaboration participation (excluding international agreements) are not significant, and the regression coefficient has a negative direction, it is important to choose appropriate ways of international collaboration. On the other hand, the number of masters and Ph.D. holders participating in the research projects shows an OR of 1.027, suggesting that it would have a small effect on the creation of patent output.

Table 8 Hosmer and Lemeshow test

Stage	Chi-square	Degree of freedom	Significance probability
1	12.131	8	.145

Table 9 Explanatory power of the analysis model

Stage	-2 Log likelihood	Cox and Snell R-square	Nagelkerke R-square
1	1253.813^2	.129	.174

4.3 Factors that Improve the Paper Output Performance of International R&D Collaborations

The analysis model of the multi-regression analysis that the significance probability of F-statistics was 0.000, implying significance, as shown in Table 11. Meanwhile, the revised R2 value was 0.245, confirming the research model's explanatory power of 25% regarding the improvement of paper output, as

Table 10 Results of logistic regression analysis of patent output creation

Variables		β*	Significance probability	Exp(B)**
	(Constant)	-1.338	.009	.262
Control	Research project year-period	.075	.058	1.078
	Chief researcher capability	.163	.000	1.177
	No. of Masters and Ph.D. holders	.026	.002	1.027
	Research project budget	.000	.486	1.000
Independent	International agreement	.188	.045	1.207
	Technical training	-.090	.635	.914
	Overseas dispatch	-.130	.152	.878
	Attraction from overseas	-.068	.040	.934
	Commissioned research projects	.242	.278	1.273
	Information exchanges	-.111	.164	.895
	Continuity_2nd year	-.136	.522	.873
	Continuity_3rd year	-.168	.609	.845
	Frequency of collaboration LN	.451	.015	1.571

*Regression coefficient, **Odds ratio(OR) shown in Table 12.

The multi-regression analysis revealed that, of the control variables, ‘research year-period’ and ‘number of masters and Ph.D. holders participating in the research projects’ had a significant effect on the improvement of paper output, as shown in Table 13. Furthermore, of the independent variables, ‘international agreements’ also had a significant effect on paper output improvement. This result is consistent with the result of Kim's study (2010), which reported that the sharing of R&D resources and co-work through international agreements had the effect of improving research output, but it is inconsistent with the finding of his study that ‘frequency of collaboration’ did not have a significant effect on paper output. This suggests that the analysis was based on research projects, presumably allowing many collaboration frequencies to be input into the analysis model, meaning that a greater frequency of collaboration does not necessarily improve paper output. Also, ‘research year-period’ has a significant effect on improving paper output, meaning that paper output cannot be improved in a short period; while the fact that a positive correlation was found between the ‘number of participating masters and PhD holders’ and the improvement of paper output was consistent with the result of Ryu's study (2011). Contrary to the authors' expectations, researchers who carried out more government-funded R&D projects as chief researchers produced fewer papers. This suggests that chief researchers’ production of papers is influenced not only by their research capability but also by such

Table 11 Significance of the analysis model

Model		Sum of squares	Degree of freedom	Mean square	F	Significance probability
3	Regression model	234.101	13	18.008	19.980	.000
	Residual	673.254	747	.901		
	Total	907.355	760			

Table 12 Explanatory power of the analysis model

Model	R	R-square	Revised R-square	Standard error of measured value	Durbin-Watson
3	.508	.258	.245	.94936	1.970

Table 13 Results of multi-regression analysis of paper output improvement

Variables		Non-standardized coefficient	Standardized coefficient	Significance probability	Multi-co-linearity statistics	
		β*	β*		Common difference	VIF
	(Constant)	.278		.006		
Control	Research year-period	.117	.205	.000	.874	1.144
	Chief researcher capability	-.061	-.095	.003	.968	1.033
	No. of Masters and Ph.D. holders	.010	.202	.000	.423	2.366
	Research project budget	7.491E-5	.052	.261	.460	2.176
Independent	International agreement	.086	.082	.020	.797	1.255
	Technical training	.029	.010	.765	.971	1.030
	Overseas dispatch	.059	.054	.138	.766	1.305
	Attraction from overseas	-.001	-.003	.950	.536	1.867
	Commissioned research projects	.007	.003	.939	.824	1.214
	Information exchanges	-.023	-.023	.506	.852	1.174
	Continuity_2nd year	.160	.062	.122	.621	1.610
	Continuity_3rd year	.120	.034	.430	.520	1.924
	Frequency of collaboration LN	.141	.110	.072	.268	3.737

* Regression coefficient

factors their leadership skills, age, and the burden of research administration.

4.4 Factors that Improve the Patent Output Performance of International R&D Collaborations

The analysis model of the multi-regression analysis revealed that the significance probability of the F-statistics was 0.000, implying significance, as shown in Table 14. Meanwhile, the revised R2 value was 0.225, suggesting that the analysis model has an explanatory power of 23% with regard to the improvement of patent output, as shown in Table 15.

The multi-regression analysis revealed that, of the control variables, 'research year-period' had a significant effect on the improvement of patent output, as shown in Table 16. Furthermore, of the independent variables, 'commissioned research project' also had a significant effect on the improvement of patent output. This is consistent with the results of the study by Choeg et al. (2011) targeting government-funded institutes, but further study should be conducted to identify how commissioned research improves patent output. As with the results of the regression analysis of paper output improvement, 'collaboration frequency' did not have a significant effect on patent output improvement, while 'research project budget size' had the most significant effect. This suggests that, unlike paper output, a huge research project budget for materials and devices is required to generate a good patent output (Choe et al., 2011). One finding of this study, i.e. that the number of participating masters and Ph.D. holders does not have

Table 14 Significance of the analysis model

Model		Sum of squares	Degree of freedom	Mean square	F	Significance probability
3	Regression model	121.956	13	9.381	10.681	.000
	Residual	368.881	420	.878		
	Total	490.837	433			

Table 15 Explanation power of the analysis model

Model	R	R-square	Revised R-square	Standard error of measured value	Durbin-Watson
3	.498	.248	.225	.93717	1.858

Table 16 Results of multi-regression analysis of patent output improvement

Variables		Non-standardized coefficient	Standardized coefficient	Significance probability	Multicollinearity statistics	
		β*	β*		Common difference	VIF
	(Constant)	.256		.066		
Control	Research year-period	.077	.135	.005	.783	1.276
	Chief researcher capability	-.045	-.071	.106	.933	1.072
	No. of Masters and Ph.D. holders	-.004	-.108	.163	.298	3.354
	Research project budget	.001	.373	.000	.313	3.197
Independent	International agreement	.020	.023	.650	.717	1.395
	Technical training	-.155	-.053	.227	.939	1.064
	Overseas dispatch	-.050	-.044	.381	.720	1.389
	Attraction from overseas	.010	.032	.639	.393	2.544
	Commissioned research projects	.295	.142	.004	.759	1.318
	Information exchanges	.012	.015	.754	.775	1.290
	Continuity_2nd year	.251	.103	.058	.608	1.644
	Continuity_3rd year	.270	.087	.138	.519	1.926
	Frequency of collaboration LN	.009	.007	.942	.207	4.827

* Regression coefficient

the effect of improving patent output, differs from the result of Ryu's study (2011), but this is presumably because the analysis in this study only targeted research projects conducted by universities.

4.5 Comparison with the Results of Previous Studies

Unlike previous studies which derived 'number of participating Ph.D.-holding researchers', 'number of international agreements', 'international exchange', and 'number of domestic and overseas society presentations' as the factors determining the creation of paper output, this study revealed that 'research year-period', 'chief researcher capabilities', and 'number of researchers sent overseas' influenced the generation of papers as research outputs, while 'research project budget' showed only a low correlation therewith. Such factors as 'number of participating masters and PhD researchers', and 'number of international agreements' influenced the improvement of performance in research projects where research outputs were produced, rather than the creation of paper outputs. In fact, the longer the research year-period, the greater the paper output produced.

Both previous studies and this study revealed that 'number of international agreements' and 'collaboration frequency' were derived as factors that influence the creation of patent output. In this study, 'chief researcher capabilities' also had a significant effect on the creation of patent output. As regards the improvement of patent output, 'research year-period' and 'number of commissioned research projects' were effective. And, unlike previous studies in which 'governmental research budget' had a low correlation with 'patent output creation', this study concluded that it had an effect on patent output improvement Table 17.

5. Researchers' Perception of International R&D Collaboration

5.1 Survey Outline

The findings of the empirical analysis have the limitations of being confined to research outputs to such as papers and patents. Thus, on site of the research field, a survey was conducted to identify the types of research outputs that may result from international R&D collaboration, and the factors which contribute to improving performance. The survey targeted the chief researchers of 1,048 international R&D collaborations conducted under government-funded R&D projects during the past three years (2008-2010). Online surveys were also conducted, to which a total of 125 respondents replied.

5.2 Researchers' Perception of Research Outputs of International R&D Collaborations

The respondents cited the expansion of international

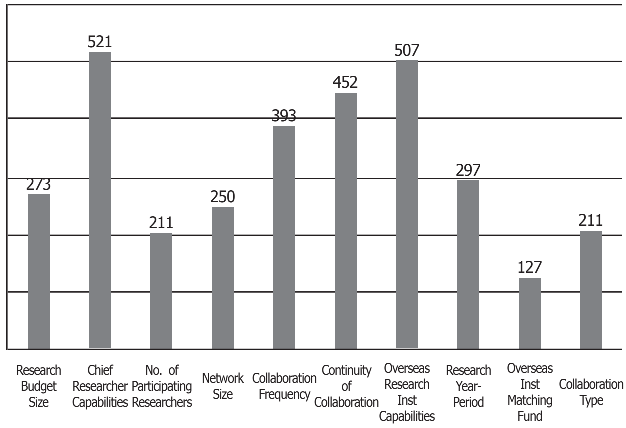
Table 17 Comparative analysis of performance-influencing factors used in previous studies and the present study

Research outputs	Performance	Performance-influencing Factors	
		Previous studies	Present study
Papers	Creation	· Participating Ph.D. holders · International agreements · International exchange ※ Governmental research budget has low correlation	· Research year-period · Chief researcher capabilities · Sending overseas ※ Governmental research budget has low correlation
	Improvement	-	· Research year-period · Participating masters and Ph.D. holders · International agreements
Patents	Creation	· International agreements · International exchange ※ Researcher capabilities have low correlation ※ Governmental research budget has low correlation	· Chief researcher capabilities · International agreements · Collaboration frequency
	Improvement	-	· Research year-period · Research project budget · Commissioned research project

collaboration human networks as the greatest research output obtainable from international R&D collaborations, as shown in Table 18. In addition, they perceived the production of papers, the fostering of domestic researchers and the gathering of overseas technical trends and information as major research outputs. Patents were indicated as the least well-regarded research output, presumably because the survey targeted universities only.

5.3 Researchers' Perception of Factors Influencing the Performance of International R&D Collaborations

As shown in Figure 4, researchers perceived 'chief researcher capabilities' and 'overseas research institute capabilities' as major performance-creating factors with regard to the output of international R&D collaborations, as shown in Table 18. This suggests that in addition to 'domestic researchers' capabilities', it is very important to collaborate with outstanding overseas research institutes. However, unlike the results of our empirical analysis, they perceived the 'continuation of international collaboration' and 'exchange frequency' as very crucial, presumably because it is difficult to build and maintain international collaboration human networks. Also, they did not regard such factors as 'research budget size', 'number of participating researchers' or 'international collaboration participation type' as significant as in the empirical analysis.



* The scores given above represent the degree of contribution to research outputs of international R&D collaborations.[3)]

Figure 4 Factors influencing the performance of international R&D collaborations

6. Conclusion

In a bid to research measures for enhancing the level of South Korea's S&T globalization through the promotion of international R&D collaboration, this study analyzed the outputs of university-conducted international collaboration on government-funded R&D projects. Based on the NTIS-data, the performance-improving factors for papers and patents were analyzed.

Table 18 Researchers' perception of research outputs of international R&D collaborations

Research outputs	No. of respondents	Response (%)
Expansion of international collaboration human networks	110	88.0
Paper output (published and presented in high-level journals)	87	69.6
Domestic research manpower (fostering of graduate school students)	62	49.6
Gathering of overseas technical trends and information	60	48.0
Research capability enhancement compared with before in international collaborations	55	44.0
Establishment of academic research groups with overseas research institutes (researchers)	51	40.8
Introduction and acquisition of overseas advanced technology	50	40.0
DDomestic researchers' entry into international communities such as international organizations, international journals' steering committees, etc.	25	20.0
Patent achievements (patent application and registration)	7	5.6

* Multiple response to survey questions

3) Of the 5-point survey scale, a weighted value (4, 5) was added to 'high' and 'very high,' and the number of multi responses was multiplied by it. Thus, the statistics were totalled.

Analysis proved again that, in the case of the creation of research paper output, the research project budget had a low correlation, while research year-period, the capabilities of the chief researcher, and the dispatch of researchers overseas all had a significant effect. In the case of the generation of patent output, chief researcher capabilities and collaboration frequency had a significant effect.

As a new result of this study, in the case of paper output improvement, research year-period had a significant effect, and in the case of patent output improvement, research year-period, and research project budget, each was found to have a significant effect. In particular, research year-period was derived as a performance-improving factor for both paper and patent outputs.

The analysis results of the 'NTIS Survey-Analysis Data' alone, which targeted only papers and patents, could have limitations of being generalized. However, they will be inducive in considering the major performance-influencing factors depending on achievements aimed at pursuing international R&D collaboration efficiently and strategically.

Meanwhile, field researchers' perceptions were surveyed in order to supplement the limitations of the research data, to identify what field researchers perceive as research achievements (besides papers and patents), and to determine which factors contribute to performance enhancement.

The field survey revealed that researchers perceived, as major achievements, the expansion of international collaboration human networks, the fostering of domestic researchers and the gathering of information on overseas technical trends, while domestic chief researcher capabilities, overseas research institute capabilities, and the continuation and frequency of collaboration were perceived as performance-influencing factors. These may be considered as additional performance-evaluating indicators of international R&D collaboration together with paper and patent outputs.

To further the analysis of international R&D collaboration performances, in addition to papers and patents, diverse performance-evaluating indicators and the corresponding ripple effects on performance should be analyzed.

References

An, Sun-gil (2009). Empirical Study on Determinants of Joint Research. Korean Academic Association of Business Administration Journal, 22(1), 291-327. (in Korean)

Choe, Ho-yeong, Choe, Chi-ho & Kim, Jeong-su (2011). Determinants of R&D Performance in Government-run S&T Research Institutes: A Study on KIST Cases, Technology Innovation Society Journal, 14(4), 791-812. (in Korean)

Choe, Tae-jin (2007). A Study on the Development of Strategic Research Management System based on the Analysis of National R&D Projects by Type, Ph.D. dissertation, Konkuk University Graduate School. (in Korean)

Grimaldi R. & von Tunzelmann N. (2003). Sectoral Determinants of Performance in Collaborative R&D Projects, International Journal of Technology Management, 25(8), 766-778.

Gwon, Jae-cheol, Mun, Jong-beom, Yu, Wang-jin & Lee, Cheol-gyu (2012). A Study on Determinants of Large-scale R&D Project Achievements: Focused on 21st century frontier R&D Projects, Technology Innovation Society Journal, 15(1), 185-202. (in Korean)

Hong, Seok-bin (2010). Global R&D Going for Open and Shared Type, LG Business Insight. Seoul: LG Economic Research Institute. (in Korean)

Jang, Geum-yeong (2010). A Study on Determinants of R&D Investment Performance: Focused on the government's industrial technology development projects, Technology Innovation Research, 18(1), 75-98. (in Korean)

Jeong, Tae-yeong (2009). Strategic Measures of Joint Research in line with Creative Practical Diplomatic Line, Seoul: Ministry of Education, Science and Technology. (in Korean)

Ju, Hye-jeong (2012). 2011 National S&T Innovation Capability Evaluation. Seoul: National S&T Commission. (in Korean)

Kim, Dae-in (2010). Empirical Research on the Effect of Research Organization's International Joint R&D Collaboration Level on R&D Achievements: Focused on South Korea's national R&D projects. Ph.D. dissertation. Konkuk University Graduate School. (in Korean)

Kim, Eun-sil (2004). Analysis of Determinants of Joint R&D Achievements by Type. a master's dissertation. Kyungpook National University Graduate School. (in Korean)

Kim, Han-ju, Jeong, Jae-yeong & Sin, Jung-gyeong (2006). A

Study on the Effect of Corporate Internationalization Level on R&D Performance. KOTRA Journal, 31(5), 173-196. (in Korean)

Kim, Hyeon-min (2012). A Study on Relation between Government R&D Projects' Collaboration Characteristics and Performance: Focused on moderating effects of project characteristics. Ph.D. dissertation. Konkuk University Graduate School. (in Korean)

Kim, Seong-jun & Yong Se-jung (2011). A Study on Determinants of Industry-Academia Joint Technology Development between SMEs and Universities. Technology Innovation Research , 19(1), 145-175. (in Korean)

Kim, Tae-hui (2012). A Study on Measures of Enhancing International Research Collaboration through National R&D Projects: Focused on basic and fundamental areas. Technology Innovation Society Journal, 15(2), 400-420. (in Korean)

Lee, U-seong (2011). OECD S&T Industry Scoreboard 2011 (Issues & Policy 2011 No. 51). Seoul: STEPI. (in Korean)

Schwartz, M., Peglow, F., Fritsch, M. & Güther, J. (2010). What determines the innovative success of subsidized collaborative R&D projects? - Project level evidence from Germany. Beiträage zur Jahrestagung des Vereins füur Socialpolitik 2010: ÖOkonomie der Familie - Session: Empirical Studies on Innovation and Financial Constraints, No. A9-V1

Ministry of Education, Science and Technology, Prospects for 2012 OECD S&T Industry, press release. (in Korean)

National Science and Technology Commission (2011). National S&T Innovation Capability Evaluation. Seoul: NSTC (in Korean)

National Science and Technology Commission. 2008, 2009, 2010, and 2011 National R&D Projects Survey and Analysis Reports. Seoul: NSTC (in Korean)

Oh, Dong-hun & An, Hye-rin (2009). Analysis of S&T International Collaboration Status, and Strategic Measures of Enhancing International Collaboration. Seoul: KISTEP. (in Korean)

Oh, Jun-byeong & Jo Yun-ae (2004). Analysis of Sucess Factors of Joint R&D: Focused on government-supported joint R&D projects, Seoul: KIET. (in Korean)

Ryu, Dong-u (2011). The Effect on Strategic Network and Organization's Capabilities on Business Performance: Focused on moderating effects of environmental dynamics. a master's dissertation. Yeoungnam University Graduate School. (in Korean)

Ryu, Yeong-su (2011). A Study on Analysis of Determinants of R&D Performance. Seoul: KISTEP. (in Korean)

Sin, Hyeong-deok, Jeong Tae-yeong, Ryu Chun-ho & Lee Jeong-ho (2010). A Study on Perception of Necessity of S&T International Collaboration: Focused on trade cost theory, performance measurement perspective, and knowledge-based perspective. Technology Innovation Society Journal, 13(4), 638-655. (in Korean)

Yang, Dong-u & Kim Da-jin (2010). The Effect of Corporate R&D Collaboration on Corporate Performance: Focused on contents industries. Korea Contents Association Collection of Papers,10(4), 306-316. (in Korean)