Asian Journal of Innovation and Policy (2018) 7.3:438-456
DOI: http//dx.doi.org/10.7545/ajip.2018.7.3.438

Determinants of Technology Transfer and Commercialization in National Research and Development: Focusing on Korea Railroad Research Projects

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Abstract This study aims to understand the importance of commercialization of research and development projects and examines key factors that allow successful technology transfer and commercialization. Given the characteristics of the railway research project, and assuming that R&D input factors would vary depending on the technology readiness level and the degree of research convergence, this study analyzes the moderating effect of each R&D input factor on technology transfer and commercialization to determine their eventual impact. Through this study, it was found that it was necessary to proceed to technology transfer and commercialization of the national research and development projects via strategic workforce composition and allocation of research funding given the subjects and development goals of R&D projects.

Keywords National research and development projects, technology development, technology transfer and commercialization, convergence, technology readiness levels

I. Introduction

The speed of technological and market changes are increasingly accelerating in response to the rapid progress in globalization and the opening of markets, and accordingly there has been an increase in the uncertainties and risks involved in technological development (Park et al., 2013). To do this National research and development (R&D) projects are investing a variety of human and material resources to develop innovative technologies for social and economic development such as solving social problems and creating markets.

Submitted, July 30, 2018; 1st Revised, September 18, 2018; Accepted, October 15, 2018
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In fact, government spending on R&D over the past decade has shown an average annual growth rate of more than 8%, exceeding the overall fiscal spending growth rate (Yoon et al., 2017). Also, institutionally, various social bases have been set up such as the introduction of a tolerance system for genuine yet failing projects in order to improve research outputs through autonomous R&D.

However, some argue that research results are less noticeable in actual applications compared to the increase in R&D budget, and there is a low level of social and substantial recognition due to the lack of outputs serving public interests that benefited people. 'OECD Economic Surveys: Korea 2016' published last year by the OECD revealed that, although Korea's R&D investment is at the top level in the world, it does not contribute much to economic growth given the scale of investment. One the one hand, it may be thought that Korea has not had sufficient time to produce outputs in view of the resources invested since the country was a latecomer in the development of science and technology compared to the US and European countries. On the other hand, such problems might have also been caused by the absence of a full-scale system to apply the research results to the market.

In order to suggest solutions to these social phenomena, many scholars have conducted various studies on technology transfer and commercialization for a number of years. However, since most studies were limited to a fragmentary point of view, studies that covered issues from the R&D stage to the commercialization stage have been rare. In addition, as input factors to promote R&D have been investigated from an individual point of view in a limited way rather than an integrated point of view, there were limitations in identifying factors that had a significant impact on technology transfer and commercialization. Particularly, there is no study on R&D projects that have a clear public purpose in special fields such as railway technology, and studies on some performance factors have been conducted only for large R&D projects such as the 21st Century Frontier Projects.

This study aims to investigate the major factors that lead to technology transfer and commercialization by improving on the limitations of previous studies and examining research input factors from an integrated point of view. In addition, given that the subject of this study is convergence research on technology development, the moderating effect of the technology readiness level (TRL), representing the degree of technology development, and the degree of convergence on research input factors for technology transfer and commercialization was examined.

II. Review of Literature and Hypotheses

1. Transfer and Commercialization of National R&D Projects

According to 'Regulations on Management of National Research and Development Projects (Presidential Decree No. 28043)', national research and development projects refer to research and development projects in the science and technology field specified by a central administrative agency on the basis of laws and regulations, for which all or part of the R&D expense is supported by direct government contribution or public funds. For the research and development outputs, research tools and materials, research facilities, and prototypes and research notebooks obtained in the process of conducting research are classified as tangible outputs, and intellectual property rights and publication rights of research reports classified as intangible outputs.

OECD has broadly defined research and development as "creative work undertaken on a systematic basis to increase the stock of knowledge and the use of this knowledge to devise new applications", and thus suggests the possibility that research and development may identify principles of events in daily life that could be applied to other fields via the exploration of new knowledge and principles, and putting those outputs into practical use.

The general concept of technology transfer and commercialization is defined as "activities and their processes for creating added value through transfer, trading, expansion and application of technologies developed from the perspective of technological innovation in the whole period" (Koo, 2014). Commercialization of technologies that are intangible assets comprises the whole period of technology growth ranging from research planning to R&D, technology trading and commercialization (Park and Park, 2014). To have technology sourced and successfully commercialized, firms search for proper modes of technology transfer (Kim and Shin, 2017).

Various resources are needed to conduct research and development. Since one of the factors considered as a source of competitive advantage is innovation through technology, investment in R&D activities is a strategically important decision making (Lee and Yang, 2015). The National Research Foundation of Korea (2013) suggested that the internal attributes of R&D projects (research subjects, scope of input resources, duration of the project, purpose of the project, etc.) could affect the classification of project outputs. In this research, based on those previous studies, the following hypotheses were formulated to investigate the impact of research input factors that promote national R&D projects on technology transfer and commercialization.

The studies that focus on technology transfer and commercialization have examined the individual effects not only on human resources, but also on material resources. Previous studies have suggested that the size of the research fund and the number of researchers generally influence the management and use of research results, such as technology transfer (Anderson et al., 2007), and studies are currently underway that look at the characteristics of technology. However, these studies are based on questionnaires and as a result, they did not set the resources actually used for the research as variables.

Even if the resources were set as variables, research was done via a fragmentary perspective in terms of the research development cost and the number of participants. In order to investigate the effects of research input factors on the technology transfer and commercialization that promote the national R&D project, this study examined not only the physical and human resources, but also the characteristics of the research project and the characteristics of the research environment. The following hypotheses were formulated:

Hypothesis 1-1. R&D expense has a positive impact on technology transfer and commercialization.

Hypothesis 1-2. The number of participating research organizations has a positive impact on technology transfer and commercialization.

Hypothesis 1-3. The number of research participants has a positive impact on technology transfer and commercialization.

Hypothesis 1-4. The degree of diversity of participants' expertise has a positive impact on technology transfer and commercialization.

Hypotheses 1-5. Collaboration has a positive impact on technology transfer and commercialization.

Hypothesis 1-6. Support for SME has a positive impact on technology transfer and commercialization.

2. Technology Readiness Level (TRL)

Technology readiness level (TRL) is a consistent and objective indicator to measure the maturity of key component technologies (Bakke, 2017). TRL is a systematic measurement tool that helps to assess the maturity of specific technologies or compare the maturity of different types of technologies in a consistent fashion (Seo, Jeon and Jeon, 2007; Mankins, 1995). The Government Accountability Office (GAO) of the US Congress, which proposed to assess the TRL in weapons-related R&D projects in order to prevent failures in the National Defense Acquisition projects, introduced the concept of TRL in 1999.

In previous studies, TRL refers to the evaluation criteria for the technology developed at a certain point of the technology life cycle (Park, 2009). Bae et al. (2009) argued that assessment of TRL of technologies could provide end-users with products with better capabilities, and subsequently suggested that the possibility of technology transfer and commercialization could be predicted through TRL. In other words, TRL allows not only managing the research objectives for technology development through R&D activities, but also identifying the stage that technology commercialization makes possible. Based on these previous studies, the following hypotheses were set to determine the impact of TRL on technology transfer and commercialization upon dividing the stages of R&D activities before R&D and after R&D.

Hypothesis 2-1. TRL before R&D has a significant impact on technology transfer and commercialization through a moderating effect on R&D input factors.

Hypothesis 2-2. TRL after R&D has a significant impact on technology transfer and commercialization through a moderating effect on R&D input factors.

3. Convergent Technology

In 2002, the concept of convergence emerged as a paradigm of future technology through a report published by the National Science Foundation (NSF) of the US (Song et al., 2009). The report stated that convergent technologies would transform the existing technology into a state of the art technology, which will allow the US economy to grow and dominate the world. In 2001, the US selected four core convergent technologies, including nano, bio, information and cognitive technologies, and increased its investment in them. Accordingly, Roco and Bainbridge (2002) defined convergent technologies as a combination of CT, NT, BT and IT. The combination of specific fields leads to the development of convergent technologies, which in turn becomes a solution to socio-economic problems.

Convergent technologies are also defined as characteristics of processes rather than specific technologies. Korea Institute of Science & Technology Evaluation and Planning defines convergent technologies as areas that involve activities such as multidisciplinary collaborative research, knowledge transfer, and exchange between academic disciplines often beyond the scope of traditional academic systems and research methods. It also means collaboration for multidisciplinary exchanges.

Stokols et al. (2010) suggested that the factors comprising the readiness of collaboration are the degree of contact among the members participating in the research, the level of maturity in interpersonal relationship, and the degree of organizational and technical support. The higher level of readiness of these would lead to successful convergence research. Thus, in this study, by deducing that the research input factors vary according to the degree of diversity of disciplines constituting the research, the following hypothesis was formulated to examine the impact of the diversity of disciplines, which is the degree of convergence, on technology transfer and commercialization.

Hypothesis 3. The degree of research convergence has a positive impact on technology transfer and commercialization through a moderating effect on R&D input factors.

III. Material and Methods

1. Data Collection and Research Subjects

As energy efficiency and unmanned operations become more socially important in the field of traffic, railway research is undergoing various convergence research such as the development of Autonomous Trail Control System and the development of HyperLoop for the future transportation technologies. In order to conduct railway research, science and technology in various fields such as electricity, electronics, and information communication are needed in addition to transportation in the classification system of National S&T Standard Classification System.

In this study, data from completed research projects as essential business (hereinafter 'major project') of government-funded research institutes in railway/public transportation/logistics fields were used.

These data are contained in the R&D plans prepared for the selection and assessment of railway research projects, and disclosed in the National Science & Technology Information Service (NTIS). The data of the project for the last three years, from January 2015 to December 2017, were used, and a total of 183 projects included. Among them, 54 projects for which the technology transfer contract was concluded for the purpose of technology transfer were classified as projects where technology transfer and commercialization occurred. Also, 95 projects for which the technology transfer contract was not concluded during the project period were classified as projects where technology transfer and commercialization did not occur. Among the projects undertaken during the same period, 34 projects that were not considered to be appropriate to provide data for variables due to project interruption lack of project plans and duplicated projects were excluded from the analysis, and thus 149 projects were finally selected as the main projects.

2. Defining Variables

2.1 Dependent Variables

Dependent variables are the status of contract for technology implementation, which means technology transfer and commercialization. The term 'contract for technology implementation' means that the research organization and implementers conclude a contract to use the technology for the design, production and sale of the product or to utilize it for the further development of the related technology.

2.2 Independent Variables

In this study, the conclusion of technology implementation contract was regarded as the occurrence of technology transfer and commercialization, and the comparative analysis between each factor conducted. Therefore, depending on whether the contract was concluded or not, the variables were classified into two groups, the case where the contract was implemented (0) and the case where the contract was not implemented (1). The independent variables were based on previous studies such as Hwang Seok-won (2006) and Chen (2009). Independent variables include research and development costs, collaborative research (Collaboration), number of participating organizations, number of participants, diversity of participating personnel (Diversity of participants' expertise), and SME support (Support projects for SME).

Also included are technology maturity, technology maturity after research and development, and research convergence. Among the independent variables, the collaborative research was divided into Yes and No, and the number of participating institutions (Number of participating organizations), was 1, 2 or more without participating organizations, and the number of participating personnel (Number of research participants), was 1-2 people, 3-5 people, 6-10 people, 11 people or more. In the above, diversity in the field of expertise for participating personnel is 1, 2, 3 and it is not for small and medium enterprises support project (Support projects for SME). The control variables are TRL before R&D, TRL after R&D, and Degree of research convergence. The variables are presented in Table 1.

Table 1 List of national R&D project data used for analysis

Variables		Definition	How to Derive Data
Independent variables	1. R&D expense	R&D budget	Total R&D expense during the entire R&D period recorded in the research plan
	2. The number of participating organizations	The number of participating R&D organizations	The number of research organizations participating in R&D recorded in the research plan
	3. The number of research participants	The number of R&D participants	The total number of participating researchers enrolled for the R&D project during the entire R&D period recorded in the research plan
	4. Diversity of participants' expertise	Diversity of participants' expertise	The number of research participants' disciplines matched with the major categories according to the standard classification system for science and technology recorded in the research plan
	5. Collaboration	Whether to collaborate with other organizations	Whether the project was a collaboration as recorded in the research plan
	6. SME support projects	Whether to support SME	Whether the project was to support SME as recorded in the research plan
Moderating variables	1. TRL before R&D	Completion of the development of key technology before R&D (introduction period, growth period or maturity period)	TRL before R&D as recorded in the research plan
	2. TRL after R&D	Completion of the development of key technology after R&D (introduction period, growth period or maturity period)	TRL after R&D as recorded in the research plan
	3. Degree of research convergence	The number of related fields of the research subject according to the classification of science and technology	The number of keywords in the research plan matched with the major categories according to the standard classification system for science and technology
Dependent variables	Technology transfer and commercialization	Contracts for the implementation of technology developed through R&D for the purpose of designing, producing and selling products or utilizing them for the development of related technologies	Whether the contract for technology implementation was concluded between 2016 and 2017

3. Data Analysis

In this study, the characteristics of the data were examined through their mean and standard deviation, and the chi-square test was conducted to determine the relationship between the analyzed factors and the success of technology transfer and commercialization. The logistic regression model calculated the odds ratio for the success of technology transfer and commercialization according to the analyzed factors and the 95% confidence interval. The moderated regression analysis was conducted to examine whether the moderating variables had a moderating effect on the impact of the analyzed factors on the success of technology transfer and commercialization. A statistical analysis was performed using the Stata 15.0 program (StataCorp, College Station, Texas).

IV. Results

1. Characteristics of Samples

The characteristics of samples used in this study are shown in Table 2. In order to derive the determinants that affect technology transfer and commercialization of the national R&D projects, 149 projects were analyzed. Among them, the contract was concluded for 54 projects (projects with the contract, 36.2%) while it was not for 95 projects (projects without the contract, 63.8%). The mean R&D expense of the former was 3.7 billion won, and it was 2.28 billion won for the latter.

Some 66.7% of the projects with the contract and 52.6% of those without the contract were collaborations, indicating the proportion of collaborations was significantly higher than those of non-collaborating projects. The mean number of participating organizations was 1.56 for projects with the contract and 1.29 for those without the contract. Thirteen percent of the projects with the contract did not have any participating organization, with 63% with one organization and 24.1% with more than one organizations, while 33.7% of the projects without the contract had zero participating organizations with 40% with one organization and 26.3% with more than one organizations, indicating that the proportion of projects with one participating organization was the highest in both cases.

These differences were statistically significant (p=0.009). In case of the number of research participants, the mean number of participants was 9.03 in the projects with the contract and 8.51 in those without the contract. Of the projects with the contract, those with 1-2 participants accounted for 16.7%, those with 3-5 participants 25.9%, those with 6-10 participants 40.7%, and those with more than 10 participants 16.7%, showing the highest proportion of projects are those with 6-10 participants. Of the projects without the contract, those with 1-2 participants accounted for 8.4%, those with 3-5 participants 40%, those with 6-10 participants 24.2%, and those with more than 10 participants 27.4%, showing the highest proportion of projects are those with 3-5 participants. These differences were statistically significant (p=0.032).

Table 2 Characteristics of sample

Variables			Whether the contract for technology implementation was concluded.[a]			*p*-value*
			With the contract	Without the contract	Total	
			n (%)	n (%)	n (%)	
Input factors	Number of projects		54(36.2)	95(63.8)	149(100)	
	R&D expense (million won)	(M±SD)	3.700±9.54	2.28±5.18	2.75±6.91	0.327
	Collaboration	Yes	36(66.7)	50(52.6)	86(57.7)	0.043*
		No	18(33.3)	45(47.4)	63(42.3)	
	Number of participating organizations (Including consignment)	(M±SD)	1.56±1.42	1.29±1.49	1.38±1.46	
		0	7 (13.0)	32 (33.7)	39 (26.2)	0.009*
		1	34 (63.0)	38 (40.0)	72 (48.3)	
		≥2	13 (24.1)	25 (26.3)	38 (25.5)	
	Number of research participants (person)	(M±SD)	9.03±6.78	8.51±6.33	8.68±6.45	
		1-2	9 (16.7)	8 (8.4)	17 (11.4)	0.032*
		3-5	14 (25.9)	38 (40.0)	52 (34.9)	
		6-10	22 (40.7)	23 (24.2)	45 (30.2)	
		≥11	9 (16.7)	26 (27.4)	35 (23.5)	
	Diversity of participants' expertise (element)	(M±SD)	1.65±0.81	1.26±0.47	1.39±0.63	
		1	36 (66.7)	70 (73.7)	106 (71.1)	0.267
		2	13 (24.1)	22 (23.2)	35 (23.5)	
		3	5 (9.3)	3 (3.2)	8 (5.4)	
	Support projects for SME	Yes	23 (42.6)	58 (61.1)	81 (54.4)	0.030*
		No	31 (57.4)	37 (39.0)	68 (45.6)	
Mode -rating variables	TRL before R&D (level)	(M±SD)	3.0±1.42	2.27±1.34	2.52±1.42	
		1-2	22 (41.5)	48 (53.3)	70 (49.0)	0.276
		3-5	28 (52.8)	40 (44.4)	68 (47.6)	
		6	3 (5.7)	2 (2.2)	5 (3.5)	
	TRL after R&D(level)	(M±SD)	6.32±1.01	5.36±2.33	101±5.97	
		1-2	0 (0.0)	7 (7.9)	7 (4.9)	0.037*
		3-5	9 (17.0)	23 (25.8)	32 (22.5)	
		6-9	44 (83.0)	59 (66.3)	103 (72.5)	
	Degree of research convergence (level)	(M±SD)	1.38±0.60	1.64±0.69	102±0.67	
		Yes	39 (72.2)	61 (64.9)	100 (67.6)	0.359
		No	15 (27.8)	33 (35.1)	48 (32.4)	

[a] Numbers may not sum to total due to missing information. M±SD; Mean ±Standard deviation, *p-value<0.1

As for the diversity of participants' expertise, the mean number of participants' expertise was 1.65 in projects with the contract and 1.26 in those without the contract. Of the projects with the contract, those with one participant's expertise accounted for 66.7%, those with two participants' expertise 24.1%, and those with three participants' expertise 9.3% while projects with one participant's expertise accounted for 73.7% of the projects without the contract, those with two participants' expertise 23.2%, and those with three participants' expertise 3.2%, indicating that both project types showed higher proportions with the smaller number of participants' expertise although there was no statistically significant difference. Some 57.4% of the projects with the contract and 39% of those without the contract were the support projects for SME and the differences were statistically significant (p=0.030).

Of the moderating variables, the mean TRL before R&D was the level 3 in the projects with the contract and 2.27 in those without the contract. Of the projects with the contract, TRL 1-2 before R&D accounted for 41.5%, TRL 3-5 before R&D 52.8%, and TRL 6 before R&D 5.7%, while TRL 1-2 before R&D accounted for 53.3% of the projects without the contract, TRL 3-5 before R&D 44.4%, and TRL 6 before R&D 2.2%, however, with no significant difference. The mean TRL after R&D was 6.3 in the projects with the contract and 5.3 in those without the contract.

Of the projects with the contract, TRL 3-5 after R&D accounted for 17% and TRL 6-9 after R&D 83%, while TRL 1-2 after R&D accounted for 7.9% of the projects without the contract, TRL 3-5 after R&D 25.8%, and TRL 6-9 after R&D 66.3% with significant difference (p=0.037).

The mean degree of research convergence was 1.38 for the projects with the contract and 1.64 for those without the contract. 72.2% of the projects with the contract showed little or no degree of research convergence of the research while the remaining 27.8% showed clear convergence. On the other hand, 64.9% of the projects without the contract showed little or no degree of research convergence and 35.1% did have the measurable degree of research convergence. However, the difference was not statistically significant.

2. Input Factors and Impact on Transfer and Commercialization

In Table 3, the logistic regression analysis was performed between independent and dependent variables in Model 1, and each of the three moderating variables was used in Model 2, Model 3 and Model 4, respectively. In addition, all the three moderating variables were used in Model 5 to determine their effects.

In Model 1, the factors affecting technology transfer and commercialization were the number of participating organizations and the support projects for SME. In Model 2, in case of use of a moderating variable TRL before R&D, the factors affecting technology transfer and commercialization were the number of participating organizations and the support projects for SME. In Model 3, in case of use of a moderating variable TRL after R&D, the factors affecting technology transfer and commercialization were the support projects for SME and TRL after R&D. In Model 4 where a moderating variable, the degree of research convergence, was used, the factors affecting technology transfer and commercialization were the number of participating organizations and the support projects for SME.

The analysis reveals that in Model 5, the factors showing statistically significant differences in technology transfer and commercialization were the number of participating organizations and the support projects for SME, indicating that only two out of the six factors of national R&D projects had a significant impact. TRL before R&D and the degree of research convergence, both moderating variables, had a positive impact on technology transfer and commercialization, but there was no statistically significant difference.

Table 3 Factors affecting technology transfer and commercialization

Variables	Model 1		VIF	Model 2		VIF	Model 3		VIF	Model 4		VIF	Model 5		VIF
	OR	P -value		OR	P -value		OR	P -value		OR	P -value		OR	P -value	
Constant	0.06	<0.001		0.05	<0.001		0.02	<0.001		0.06	<0.001		0.02	<0.001	
R&D expense	1.60	0.161	2.15	1.61	0.161	2.15	1.44	0.292	2.23	1.67	0.130	2.16	1.45	0.286	2.28
Number of participating organizations	1.97	0.042**	2.56	1.82	0.077*	1.59	1.61	0.171	2.61	1.93	0.051*	2.56	1.45	0.241	2.62
Number of participating researchers	0.78	0.340	1.30	0.86	0.552	1.29	0.86	0.556	1.37	0.82	0.453	1.31	0.90	0.709	1.39
Collaboration	0.78	0.679	1.89	0.70	0.560	1.99	0.60	0.413	1.97	0.75	0.390	1.92	0.58	0.396	2.01
Diversity of participants' expertise	1.56	0.161	1.09	1.58	0.159	1.10	1.73	0.104	1.13	1.60	0.141	1.09	1.80	0.080*	1.13
Support projects for SME	3.35	0.068*	1.09	3.54	0.067*	3.18	4.06	0.047**	3.15	3.74	0.051*	3.04	4.73	0.034**	3.20
TRL before R&D	-	-		1.34	0.403	1.19	-	-	-	-	-		0.96	0.909	1.40
TRL after R&D	-	-		-	-		2.21	0.061	1.22	-	-		2.27	0.068*	1.43
Degree of researches convergence	-	-		-	-					0.55	0.140	1.05	0.59	0.197	1.05
$X^2(p)$	16.96(0.009)			11.39(0.123)			16.87(0.018)			16.66(0.020)			20.73(0.014)		
Negelkerke R^2	0.107			0.105			0.153			0.146			0.186		

Note 1. OR: Odds Ratio; *p<0.1, **p<0.05, ***p<0.01

Note 2. Model 2 = TRL before R&D

Note 3. Model 3 = TRL after R&D

Note 4. Model 4 = Degree of research convergence

Note 5. Model 5 = TRL before R&D, TRL after R&D and degree of research convergence

It was shown that TRL after R&D had a statistically significant positive impact on technology transfer and commercialization. In the analysis of the impact of moderating variables on technology transfer and commercialization, it could be seen that the factors affecting technology transfer and commercialization have changed along with the magnitude of their impact as moderating variables TRL before R&D, TRL after R&D and the degree of research convergence were incorporated.

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3. Moderating Effect of TRL Before R&D

Table 4 shows the analysis results of the moderating effect of TRL before R&D on the impact that input factors of national R&D projects have on technology transfer and commercialization. It was found that there was no statistically significant difference for all factors. It should be taken into consideration that these resulted from the explanatory power limited to six factors of national R&D projects used in this study among numerous factors affecting technology transfer and commercialization.

Table 4 Moderating effects of TRL before R&D

	B	Std. Er	OR	p-value
R&D expense * TRL before R&D	-0.09	064	0.92	0.437
Number of participating organizations * TRL before R&D	0.01	0.62	1.01	0.984
Number of research participants * TRL before R&D	-0.36	0.50	0.70	0.470
Collaboration * TRL before R&D	-0.42	1.31	0.66	0.751
Diversity of participants' expertise * TRL before R&D	0.46	0.68	1.58	0.502
Support projects for SME * TRL after R&D	-0.53	1.44	0.59	0.712

$p<0.1$, **$p<0.05$, ***$p<0.01$; Negelkerke $R^2=0.199$

4. Moderating Effect of TRL After R&D

Table 5 shows the analysis results of the moderating effect of TRL after R&D on the impact that input factors of national R&D projects have on technology transfer and commercialization. Among the input factors, R&D expense and the number of research participants showed a statistically significant difference. This results show that R&D expense-dependent technology transfer and commercialization will vary depending on TRL after R&D. This indicates that the higher TRL after R&D will lead to the higher degree of technology transfer and commercialization for R&D expense.

Table 5 Moderating effect of TRL after R&D

	B	Std. Er	OR	p-value
R&D expense * TRL after R&D	3.57	1.57	16.9	0.025**
Number of participating organizations * TRL after R&D	-1.20	1.01	0.89	0.719
Number of research participants * TRL after R&D	-1.49	0.92	0.22	0.093*
Collaboration * TRL after R&D	-0.40	2.71	0.16	0.375
Diversity of participants' expertise * TRL after R&D	0.12	1.03	0.97	0.973
Support projects for SME *TRL after R&D	-0.55	2.37	1.33	0.878

$p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$; Negelkerke $R^2=0.274$

5. Moderating Effect of the Degree of Research Convergence

Table 6 shows the analysis results of the moderating effect of the degree of research convergence on the impact that input factors of national R&D projects have on technology transfer and commercialization. It was found that the diversity of participants' expertise had a statistically significant moderating effect.

Table 6 Moderating effect of the degree of research convergence

	B	Std. Er	OR	p-value
R&D expense * Degree of research convergence	0.59	0.83	1.80	0.477
Number of participating organizations * Degree of research convergence	0.21	0.76	1.23	0.783
Number of research participants * Degree of research convergence	-0.76	0.68	0.47	0.264
Collaboration * Degree of research convergence	1.46	1.67	4.28	0.384
Diversity of participants' expertise * Degree of research convergence	2.28	0.98	9.73	0.020**
Support projects for SME * Degree of research convergence	-0.50	1.69	0.61	0.766

$p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$; Negelkerke $R^2=0.269$

V. Discussion and Conclusion

In this study, a regression analysis was carried out to assess the impact of research input factors set as independent variables on technology transfer and commercialization. In addition, changes in the impact of each of TRL before R&D, TRL after R&D and the degree of research convergence, which are moderating variables, on the input factors of national R&D projects were examined also through the regression analysis.

Results of this study showed that the factors that had a statistically significant difference in technology transfer and commercialization among independent variables were the number of participating organizations and support projects for SME, showing that only two out of the six factors of national R&D projects had a significant impact.

For the purpose of technology transfer and commercialization of research achievements to take place, various roles are needed besides technical expertise such as marketing appropriate to the market and exploitation of developed technologies. All organizations exist based on well-defined goals and roles of each organization.

Therefore, the diversity of the participating institutions means that the professional roles of each institution are divided into the respective professional roles to achieve the common goal. For that reason, it is possible to search various ways to solve the problem, so the use of technology to implement the technology transfer and commercialization increases, which has a significant influence on the commercialization of the technology.

The SME (Small and Medium size Enterprise R&D project), support project used in this study consists of supporting excellent product development, supporting overseas advancement, SME support project related to related organizations, and providing one-stop tailored technical service to consumers (technology commercialization). All of these projects are aimed at commercialization, and Chu (2014) said that government investment in SMEs would affect the technology commercialization. The development of new technologies and new products through convergence (industrial convergence) between industries is a very important factor for the sustainable growth (sustainable development) and survival (survival) of the enterprise (Cho and Lee, 2013; Chesbrough, 2006).

SMEs develop new products through R&D to generate sales in markets where technology changes are accelerated and product life cycles are shortened. Therefore, the SME support project will focus on preventing the developed technology from being used, and these goals will have a significant impact on the technology commercialization.

The analysis of the moderating effect of TRL after R&D showed that R&D expense and the number of research participants had a statistically significant positive impact on technology transfer and commercialization, while the level of research convergence had a statistically significant positive impact on the diversity of participants' expertise. In addition, more R&D expense will be spent and the number of researchers decreases when the TRL reaches a higher level, which has a significant impact on technology transfer and commercialization. In other words, when research on technology transfer and commercialization was conducted, the R&D expense for field research would increase and a compact force of experts plays an important role rather than a large number of human resources. This suggests that as the R&D approaches to commercialization stage, the experts should participate as researchers, which will increase the success rate of technology transfer and commercialization. Hence, this implies that the efforts for human resource development should continue. Through this study, it was necessary to construct a consortium and compose a team of researchers that can share roles in view of the characteristics of research to be conducted rather than simply investing a large amount of research funds, in order to increase the success rate of technology transfer and commercialization. It was found that the formation of inappropriate organizations was a factor that hindered technology transfer and commercialization of the research results, and the input of appropriate researchers in the right roles could lead to a significant impact on technology transfer and commercialization by developing excellent technologies as outputs.

The analysis of the moderating effect of Convergence research also has a significant impact on technology transfer and commercialization if the researchers involved have a wide range of expertise. Researchers are the driving force for research. To maximize synergy, multidisciplinary knowledge is essential for multidisciplinary convergence research (Lee et al., 2009). Convergence research is a study in which various fields are cooperating to develop innovative technology. In this study, it was found that the specialization of research subjects and researchers is very important not only in research, but also in transfer and commercialization.

This study has provided an opportunity to examine the efficient investment and appropriate components for national R&D projects. If the results of this study are developed more systematically and in depth, subsequently leading to the development of purpose-specific component manuals of the national R&D projects in the future, the commercialization rate of technologies derived from the research results will increase. These results will contribute to determining the optimal conditions for commercialization of convergence research and establishing a social basis to lead in the era of the Fourth Industrial Revolution by providing a theoretical basis to distribute limited resources efficiently and to create new markets. In addition, a new direction of technology transfer and commercialization research has been established by demonstrating that the convergence variable is an important variable in technology transfer and commercialization.

The limitations of this study are as follows: First, according to the regression analysis, the explanatory power is low even though the various factors have a significant correlation. The reason for this is presumably due to the small sample size.

Second, since this study analyzed the research subjects in a specific field, it is necessary to analyze the research subjects in more diverse fields to develop a general theory. In addition, due to the limitations of the data, this study did not cover the broad viewpoints of technology transfer and commercialization. Since the national R&D projects are diverse, even including financial support projects, studies will be more realistic and can contribute better to society if more diverse data are used in the future.

Reference

Anderson, T.R., Daim, T.U. and Lavoie, F.F. (2007) Measufing the efficiency of university technology transfer, Technovation, 27(5), 306-318.
Bae, Y.H. and Choi, S.C. (2009) Calculation TRL using integration readiness between technologies for supporting technology-transition of defense technologies to the defense weapons system, Management Science, 26(3), 157-167.
Bakke, K. (2017) Technology readiness levels use and understanding, Master's thesis, University College South-East Norway.
Chen, C. (2009) Technology commercialization, incubator and venture capital and new venture performance, Journal of Business Research, 62(1), 93-103.
Chesbrough, H.W., Vanhaverbeke, W. and West, J. (2006) Open Innovation: Researching an New Paradigm, USA: Oxford University Press.
Cho, C.W. and Lee, S.J. (2013) Study on the cooperation model for fusion-technology development in SMEs, Korean Institute of Industrial Engineers, 39(3), 198-203
Hwang, S.W. (2006) SCI and assessment of research and development outputs, Science and Technology Policy Institute, Korea.
Kim, Y.J and Shin, S.J. (2017) What Causes Technology Commercialization to Succeed or Fail after Transfer from Public Research Organizations, Asian Journal of Innovation and Policy, 6(1), 23-44.
Koo, B.C. (2014) Derivation and empirical analysis of critical factors that facilitate technology transfer and commercialization of research outcome, Asia-Pacific Journal of Business Venturing and Entrepreneurship, 9(5), 69-81.
Lee, J.H. and Yang, J.W. (2015) The creation of rirm competitiveness through R&D investment: the roles of path dependence and resource characteristics, Journal of Strategic Management, 18(3), 71-96.
Lee, S.J., Hwang, E.H., Nam, K.E. and Choi, C.W. (2009) A study on the cultivation of interdisciplinary scientists by reformation of the traditional university undergraduate course, Journal of Korea Technology Innovation Society, May, 265-277.
Organisation for Economic Co-operation and Development (1992) Technology and economy: the key relationships, economics of science and technology, Research Group for Economics of Technology and Evolution, Translated by Lee, G. et al.
Park, K.J. (2009) Establishment of TRL assessment and the cases of its application, Journal of the Korean Society of Systems Engineering, 43-48.
Park, S.Y., Son, J.K., Seo, J.H. and Seo, J. (2013) Performance evaluation index of TRM: a Korean case for SMEs, Asian Journal of Innovation and Policy, 2(1), 63-96.
Park, W. and Park, H.Y. (2014) A study on business ecosystem model for technology commercialization: focused on its application to public R&D commercialization, Journal of Korea Technology Innovation Society, 17(4), 786-819.
Seo, J.H., Jeon, K.Y. and Jeon, H.S. (2007) A study on the application of TRL to the development of parts and materials, Journal of Korea Technology Innovation Society, 10(4), 789-807.
Song, J.G., Lee, J.W., Yoo, E.S., Song, C.W., Kim, W.D., Park, Y.I., Lee, J.G., Choi, K.R., Hong, Y.R. and Yoon, J.H. (2009) Science and technology based foresight

analysis for national development, Science and Technology Policy Institute, Policy Research 2009-10.
Stokols, D., Hall, K.L., Moser, R.P., Feng, A., Misra, S. and Taylor, B.K. (2010) Cross-disciplinary team science initiatives: research, training, and translation in Frodeman, R., Klein, J.T. and Mitcham, C. (Eds.) The Oxford Handbook of Interdisciplinarily, Oxford and New York: Oxford University Press.
Yoon, Y.J. and Oh, S.S. (2017) The types of R&D projects and the size of corporations affecting patent citations: focusing on the government-funded R&D projects carried out by corporations, The Journal of Intellectual Property, 12(1), 183-212.