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Factor Analysis for Improved Commercialization of Technologies Developed on Korea National R&D Projects

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Abstract

This research was aiming at comparing and analyzing commercialization efficiency of national R&D projects of government ministries to improve technology commercialization performance of national R&D projects by applying Data Envelope Analysis (DEA) method. Through correlation analysis of various factors, several measures were proposed for the improvement of commercialization results. It was indicated from this research that government investment and policy were vital factors in improving technology commercialization through national R&D projects.

Keywords: Commercialization of Technologies, Factor Analysis, National R&D Projects

1. Introduction

In the context of the recent globally ongoing economic recession, to secure future growth, many major advanced countries have continuously invested in projects and strive to commercialize the technologies developed from those projects as an effort to overcome the crisis. Korean government has also emphasized the importance of knowledge resource including technologies and is making great efforts in technology commercialization, demonstrated by the establishment of 'Promotion plan for technology transfer and commercialization'. As shown above, through the commercialization of the knowledge and technology developed from the government's continuous investment in R&D, new high added values can be created to overcome the crisis and accelerate Korea's entry into the knowledge based economy. Government investment R&D has been recognized as a vital factor determining the knowledge level of national economy as well as national productivity and economic growth rate[1].

Due to this trend, technology transfer, commercialization and patent management are getting into the limelight as promising businesses, and the importance of R&D business through convergence and opening is being increasingly recognized.

Korean government currently also emphasizes the importance of knowledge resources, realizing the necessity of changing into the first mover, not just a fast follower, through creative innovation and technology utilization and spares no effort to invest in R&D. However, in spite of these government's efforts, the commercialization and productivity of technologies from Korean government's R&D still falls short of major advanced countries'.

In order to improve the commercialization of national R&D technologies, this research was aiming at analyzing various external factors, such as government support and characteristics of technologies to understand which has greater effect on commercialization by comparing and analyzing between Korea government ministries, without focusing on a specific technology. It includes the comparison between Rural Development Administration (RDA),

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whose technologies have distinctive features and Small and Medium Business Administration (SMBA), whose primary mission was to support transfer and commercialization of various technologies.

Among various external factors such as government's support and technology characteristics etc. which have greater influence on commercialization was also analyzed. In this study, the projects with the highest efficiency were selected after analyzing the efficiency of those chosen as national R&D projects. By analyzing factors in the selected projects and selecting those that can raise the efficiency of national R&D projects, the study presented some commercialization improvement measures.

In the 1st chapter, the purposes of this research and current status are presented. The 2nd chapter discusses the relevant literature on national R&D commercialization and in the 3rd chapter, efficiency and factors are analyzed. Lastly, the 4th chapter proposes some commercialization improvement measures for national R&D projects based on the derived analysis results and policy implications. The implications from this study are expected to contribute to government activities relating to national R&D commercialization policy.

2. Literature Review

2.1 Current Status of Technology Transfer and Commercialization

Depending on the research fields and application technologies of researchers, the scope of technology commercialization spans from research on technology commercialization, merchandizing and industrialization etc., to technology market. However, technology commercialization is normally considered as a process to grow a specific technology into a business unit i.e., from innovative and creative idea to the stage of product development, production, market entry and sales.

Technology commercialization has been activated in full-scale after the establishment of Bayh-Dole Act in 1980, which was about protecting intellectual property rights of private research institutes and universities through government support. With the establishment of the Act, R&D commercialization of private research institutes and universities through patenting has become a key issue. In case of the U.S.A., together with the increasing outcomes of intellectual property rights of private research institutes, commercialization to utilize institutes' research outcomes was accelerating and many venture businesses were created. As a result, the U.S.A. became the country of the most active technology business. Korea has also strived to invest in R&D, having developed technology commercialization supporting programs and promoted venture capital. Technology Transfer Promotion Law (2002) and Industrial Education Promotion Act (2003) benchmarked Bayh-Dole Act to improve industrial competitiveness through technologies created from universities.

As Daedeok Science Complex in Daejeon was designated as a R&D Special Zone in 2005, it has been promoted in earnest as a cluster for technology commercialization and this has been continuing so far. Similarly, small and medium enterprises have been playing a vital role in the generation of technology commercialization by diffusing the technologies. The proportion of small or medium-sized businesses is 52.8% in added value and 50.6% in production , signifying that technology innovation and R&D of small or medium-sized businesses have great effect on national competitiveness.

In the past, the Korean government supported to promote small or medium-sized businesses, beginning with imitation R&D to copy advanced technologies of developed countries. However, at present, it supports small or medium-sized businesses through technology commercialization and venture promotion to generate high added value and many researches are conducted in accordance with this.

2.2 Technology Transfer and Commercialization Facilitating Factor

Currently studies on main factors to promote technology transfer are being continuously conducted. According to Copper's research, rather than providing full support for new product development, the support to overcome market uncertainty when a new developed product enters into the market increases success probability of the business.

His research results stated that successful commercialization may not depend on the effectiveness of the technology. According to Jolly's research, technology commercialization is divided into 5 stages of activities from technical stage to marketing stage. In his explanation of the entire periodic processes, 4 transition activities focus on procuring and delivering all resources necessary toward the next stage, and success in technology commercialization depends on success in each transition activity.

In order to promote commercialization, support is needed in all stages, from R&D planning to outcome generation, management and utilization, and follow-up management. Therefore, the government are continuously providing support to promote commercialization and many researchers have continued their studies on government supporting policy and the direction.

However, preceding studies on factors facilitating technology commercialization have analyzed mostly qualitative data and questionnaires. This research improved the reliability of those studies by analyzing the quantitative data of national R&D information through research analysis evaluation.

3. Analysis

3.1 Analysis Methodology

This research applied DEA (Data Envelopment Analysis), a non-parametric linear programming model to infer optimal efficiency by measuring relative efficiency among different groups. It analyzed also the correlation between commercialization efficiency and factors having effects on improving commercialization through analyzing spearman correlation that identifies non-parametric correlation.

DEA method was initiated from an analysis of Charnes, Cooper and Rhodes. After their analysis, many researchers have applied DEA to numerous studies. One advantage of DEA method is that it does not have presumptions on function type, which has enabled its application with various methodologies to measure efficiency in many fields including non-profit, regulated sector and private sectors.

This research analyzed 21 projects of Small and Medium Business Administration (SMBA) and 52 projects of Rural Development Administration (RDA) utilizing NTIS data, supplied by KISTI. It only utilizes the data of those that have commercialization outcomes among project data (67,139 cases) of Small and Medium Business Administration (SMBA) and the data (24,523 cases) of Rural Development Administration (RDA) which are researches, analyses and evaluations completed between 2002 and 2012, and all data from Korea National R&D Project.

3.2 Analysis Model

Basic CCR model involving Constant Returns to Scale (CRS) in DEA analysis method was not suitable for this research. Therefore, BCC model applying Variable Returns to Scale (VRS) was used for analysis of this research. The model applied above is shown as follows;

$$\theta^{k,*} = \min_{\theta,\lambda} \theta$$

Subject to

$$\theta^k x_m^k \geq \sum_{j=1}^{J} x_m^j \lambda^j \left(m = 1, 2 \ldots, M\right);$$

$$y_n^k \leq \sum_{j=1}^{J} y_m^j \lambda^j \left(n = 1, 2 \ldots, N\right);$$

$$\sum_{j=1}^{J} \lambda^j = 1;$$

$$\lambda^j \geq 0 \left(j = 1, 2, \ldots J\right) \tag{1}$$

*M=Input, N=Output, J=Observed Value

This model is similar to CCR one, there is a difference in point that it has additionally convexity as a necessary condition. BCC model measures pure efficiency, while CCR measures overall technological and scale efficiency. In order to indicate the technological relationship that exists between input of production factors and output of products, this research compared and analyzed the efficiency of the projects of Small and Medium Business Administration (SMBA) and Rural Development Administration (RDA).

3.3 Input Factors

Overall processes from R&D investment, activity and outcomes have been used as Input factors of R&D investment factors. Particularly, R&D expenditure is used as a proxy to accumulated knowledge, potential of technology and new product development , expenditure as an input factor is appropriate. Research manpower is another input factor, which represents the amount of technological knowledge. From the viewpoint of knowledge base, tacit knowledge, defined as know-how about research, technology and practical knowledge accumulated through experience, appears to have a large effect on outcomes. Research manpower seems to have influence on re-production of technologies and products through knowledge production and accumulation by the manpower's experience and interaction with other people. As this research was for studying factors influencing commercialization for government policy direction of R&D projects, R&D investment of government ministries and research manpower of projects have been set as input factors for analysis.

3.4 Output Factors

There are many differences among output factors of R&D activities according to different researchers. In general, outcomes from research activities, such as the number of patents or papers, are mainly used as an index for the results or outputs of R&D activities. However, according to preceding literature, patents or papers are incomplete index. Particularly, due to the characteristics of institutes invested by government, R&D activities are considered to only resolve issues in their business activities. Therefore, there is a problem in taking patents or papers as factors of output.

Hence, this research analyzed the number of commercializing cases and licensing fee by project as outputs, considering results of technology transfer or commercialization as outcomes. The number of commercialization included results directly made by technology holders such as process improvement, merchandizing and business start-up, and outcomes made through technology transfer. Licensing fee was set as outcomes by adding up collected licensing fees through commercialization.

3.5 Correlation Analysis affecting Factors Variable Setting

The factors affecting technology commercialization are largely divided into internal technologies' characteristics and external environmental factors during commercialization. Regarding internal characteristics of technologies, technology life cycle, technology R&D stage and whether classified as future prospective new technologies (6T) were selected. It was based on an assumption that, upon commercializing, commercialization would be fulfilled well if the purpose of technology was clear and ready to be launched into the market.

In terms of external environmental factors, industry-university-institute collaboration form subjects of conducted researches and commercialization form were selected. As industry, university and institute have different characteristics, the influence of each organization was measured about which organization led commercialization.

Table 1. Input and output data of Rural Development Adminstration (RDA) By Project (Unit: Person and Won)

		Average	Maximum Value	Minimum Value	Standard Deviation
Input	Research manpower	2722.076923	31756	18	5268.267249
	Research investment by government	52,868,980,038	280,054,321,998	4,329,000,000	58,635,735,939
Output	The number of commercialization	74.88461538	531	1	108.9889998
	Total licensing fees	98,526,081	1,695,656,000	200,000	268,361,126

Table 2. Input and output data of Small and Medium Business Administration (SMBA) By Project (Unit: Person and Won)

		Average	Maximum Value	Minimum Value	Standard Deviation
Input	Research manpower	622.2380952	5023	4	1107.58927
	Research investment by government	13,300,923,381	113,000,000,000	90,000,000	24,465,290,552
Output	The number of commercialization	499.2857143	7472	2	1570.410021
	Total licensing fees	2,359,133,151	23,249,784,872	5,230,200	5,069,204,528

Technology commercialization form was divided into technology transfer type and another type in which technology holders directly start up a business, make products from it or improve a process. It was based on the assumption that a person holding technology or with a good understanding of the technology would make better results than technology transfer, if he or she directly merchandizes it.

4. Analysis Results

4.1 Efficiency Analysis Results

The estimated efficiency demonstrates the results of a model with 2 inputs and 1 output by selecting the number of commercialization cases and licensing fee profits as inputs. Project efficiency was ranked by setting an arbitral project code for each project of a ministry.

The above analysis results indicate that most top 20 efficient projects belong to Small and Medium Business Administration (SMBA). According to the project numbers of two ministries used as analysis data, the numbers of Rural Development Administration (RDA) were higher than the ones of SMBA, between 21 projects by SMBA and 52RDA respectively.

However, the project efficiency of SMBA appeared to be higher than the counterpart. Project 12 of SMBA has value 1 in terms of efficiency of the number of cases and licensing fee, showing high efficiency. In terms of efficiency of licensing fee, all projects, except one project, belong to SMBA. This result demonstrates that many factors, such as the characteristics of ministries and difference of technologies, have effects on commercialization.

4.2 Correlation Analysis

Correlations between internal characteristics of ministries and commercialization, and between external environmental factors and commercialization were analyzed. The following table shows the correlation between technology life cycle and commercialization outcomes by ministry.

In case of Rural Development Administration (RDA), technologies in introductory period show the biggest correlation with commercialization with the value at 0.34, and technology life cycle basic research development stage shows the biggest correlation coefficient as 0.35, In terms of promising futuristic technology class (6T), NT technology indicates 0.35 of correlation coefficient. All factors are getting significant values.

Table 3. Correlation between technology life cycle factors and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient				
			1	2	3	4	5
Commercialization Outcomes	98526080.96	270979345.45	1				
Introductory Period	137.38	257.24	0.34*	1			
Maturity Period	37.65	74.26	0.12	0.74***	1		
Growth Period	153.27	248.04	0.14	0.81***	0.84***	1	
Decline Period	0.44	1.30	-0.22	0.23	0.39**	0.36**	1

* P<0.05, ** P<0.01, *** P<0.001

Table 4. Correlation between technology R&D stage factors and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient			
			1	2	3	4
Commercialization Outcomes	98526080.96	270979345.45	1			
Development Research	94.82	154.68	0.2	1		
Basic Research	124.36	274.26	0.35*	0.67***	1	
Applied Research	122.79	182.84	0.25	0.76***	0.80***	1

* P<0.05, ** P<0.01, *** P<0.001

Table 7 to 9 shows the relation between internal factors and commercialization status of SMBA. It looks different from RDA in many areas. Technologies of SMBA show that those in growth period indicate a significantly high correlation coefficient at 0.98. In terms of future prospective new technologies (6T), technologies in ET field show the highest correlation with correlation coefficient of 0.92. In terms of research stage, technologies in development research shows correlation coefficient of 0.98 and all factors indicate high significance.

When comparing internal factors of two ministries, factors of SMBA show respectively higher correlation with commercialization and significance than those of RDA. It demonstrates that project characteristics of SMBA are more suitable for commercialization than those of RDA.

Table 9 to 11 shows the correlation between external factors and commercialization of RDA. In terms of correlation among the subjects of conducted researches, there is no significant value. However, 'national institute' has the highest value in terms of the number of projects. It means that most project tasks are carried out by national institutes. There is no significant value in the correlation between cooperated organization and commercialization. However, the cooperation with universities shows the high-

Table 5. Correlation between technology future prospective new technology (6T) factors and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient					
			1	2	3	4	5	6
Commercialization Outcomes	98526080.96	270979345.45	1					
BT	292.12	470.46	0.25	1				
CT	1.92	6.85	0	0.13	1			
ET	24.40	86.46	0.24	0.49***	0.16	1		
IT	3.37	9.46	0.26	0.50***	0.45***	0.50***	1	
NT	0.58	1.53	0.35*	0.56***	0.2	0.46***	0.45***	1

* P<0.05, ** P<0.01, *** P<0.001

Table 6. Correlation between technology life cycle factors and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient				
			1	2	3	4	5
Commercialization Outcomes	2359133151.43	5194388921.63	1				
Introductory Period	10.667	27.36	0.54*	1			
Maturity Period	37.286	136.10	0.63**	0.92***	1		
Growth Period	65.381	96.15	0.98***	0.48*	0.61**	1	
Decline Period	0.048	0.22	0.26	0.28	0.44*	0.28	1

* P<0.05, ** P<0.01, *** P<0.001

Table 7. Correlation between technology R&D stage factors and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient			
			1	2	3	4
Commercialization Outcomes	2359133151.43	5194388921.633	1			
Development Research	111.857	244.702	0.98**	1		
Basic Research	0.095	0.436	0.37	0.37	1	
Applied Research	2.238	5.281	0.63**	0.62	0.51*	1

* P<0.05, ** P<0.01, *** P<0.001

Table 8. Correlation between future prospective new technology (6T) factors and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient						
			1	2	3	4	5	6	7
Commercialization Outcomes	2359133151.43	5194388921.63	1.00						
BT	13.10	33.10	0.83***	1.00					
CT	1.29	3.24	0.66**	0.75***	1.00				
ET	19.81	39.40	0.92***	0.76***	0.56**	1.00			
IT	34.62	76.25	0.84***	0.84***	0.83***	0.71***	1.00		
NT	5.19	10.67	0.83***	0.81***	0.62**	0.75***	0.79***	1.00	
ST	0.76	2.00	0.63**	0.39	0.44*	0.58**	0.55**	0.61**	1.00

* P<0.05, ** P<0.01, *** P<0.001

Table 9. Correlation between industry-university-institute factors and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient					
			1	2	3	4	5	6
Commercialization Outcomes	98526080.96	270979345.45	1					
National Institute	292.12	470.46	0.24	1				
Industry	1.92	6.85	0.13	0.35*	1			
University	24.40	86.46	0.24	0.42**	0.85***	1		
Government Ministry	3.37	9.46	0.07	0.28*	0.85***	0.81***	1	
Government funded institute	0.58	1.53	0.25	0.30*	0.85***	0.72***	0.73***	1

* P<0.05, ** P<0.01, *** P<0.001

Table 10. Correlation between industry-university-institute collaboration factors and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient				
			1	2	3	4	5
Commercialization Outcomes	98526080.96	270979345.45	1				
University	49.42	93.97	0.14	1			
National Institute	29.25	48.11	0.24	0.84***	1		
Foreign Research Institute	5.23	16.91	0.16	0.51***	0.41**	1	
Industry	16.73	30.01	0.22	0.87***	0.75***	0.53***	1

* P<0.05, ** P<0.01, *** P<0.001

est value. In terms of correlation with commercialization form, Merchandizing through technology transfer shows the highest correlation value of 0.28 and P value interpreted as significant.

When analyzing correlation of external factors of SMBA, in terms of research conducting subject, small or medium-sized industries show a high correlation coefficient of 0.98 which is a significant value. In terms of cooperated organization, cooperation with industry shows the highest correlation coefficient at 0.92. In terms of commercialization form, business start-up through technology transfer shows the highest correlation coefficient at 0.97. It demonstrates that many external factors of SMBA have high correlation coefficient and significant value.

Table 11. Correlation between commercialization form and outcomes (RDA)

Variable	Average	Standard Deviation	Correlation coefficient					
			1	2	3	4	5	6
Commercialization Outcomes	98526080.96	270979345.45	1.00					
Technology holder's direct Commercialization -Process improvement	0.04	0.19	−0.09	1				
Technology holder's direct Commercialization–Merchandizing	0.04	0.19	−0.09	1.00***	1.			
Technology holder's direct Commercialization–Business start-up	0.02	0.14	−0.21	0.70***	0.70***	1.		
Technology Transfer -Merchandizing	73.50	109.20	0.28*	0.27	0.27	0.14	1.	
Technology Transfer–Business start-up	1.29	2.48	0.14	0.31*	0.31*	0.21	0.13	1.

* P<0.05, ** P<0.01, *** P<0.001

Table 12. Correlation between industry-university-institute factor and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient			
			1	2	3	4
Commercialization Outcomes	2359133151.43	5194388921.63	1			
University	0.62	2.04	0.56**	1		
Industry	111.86	247.36	0.98***	0.56**	1	
Government funded institute	0.71	3.27	0.26	0.61**	0.26	1

* P<0.05, ** P<0.01, *** P<0.001

Table 13. Correlation between industry-university-institute collaboration factor and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient			
			1	2	3	4
Commercialization Outcomes	2359133151.43	5194388921.63	1			
University	10.62	30.85	0.55*	1		
National Institute	13.29	37.58	0.82***	0.45*	1	
Industry	52.19	77.91	0.92***	0.4	0.80***	1

* P<0.05, ** P<0.01, *** P<0.001

5. Conclusion

This research analyzed factors to improve commercialization by comparing the efficiencies of the outcomes of SMBA and those of RDA. When analyzing efficiency with the number of cases and licensing fee as inputs, SMBA showed higher efficiency than RDA in terms of inputs.

The correlation analysis results from internal and external factors of each ministry showed that two ministries had significantly different results. The results

Table 14. Correlation between commercialization form and outcomes (SMBA)

Variable	Average	Standard Deviation	Correlation coefficient					
			1	2	3	4	5	6
Commercialization Outcomes	2359133151.43	5194388921.63	1					
Technology holder's direct Commercialization -Process improvement	0.10	0.44	−0.04	1				
Technology holder's direct Commercialization–Merchandizing	0.29	1.10	0.25	−0.07	1			
Technology holder's direct Commercialization–Business start-up	0.33	0.73	0.21	0.50*	0.25	1		
Technology Transfer -Merchandizing	1.00	2.49	0.56**	−0.14	0.62**	−0.06	1	
Technology Transfer–Business start-up	112.57	248.83	0.97**	0	0.15	0.18	0.57**	1

* P<0.05, ** P<0.01, *** P<0.001

indicated that the factors effecting commercialization were different according to the ministry's characteristics and external environmental influence. This can be seen as a result of the ministries characteristics. As the main mission of SMBA is to support the business activities of small or medium-sized and business start-up, in terms of external environmental factors, it seems that mainly small or medium business takes the lead in conducting researches or in the field of cooperation.

On the other hand, as RDA focuses on improving the competitiveness of rural industry through developing and supplying agricultural science and technology and training, researches are mainly conducted by government or universities or in cooperation. It seemed that the focus is on product development and merchandizing rather than business start-up. These ministry characteristics appeared to have an effect on internal technology factors as well. According to correlation analysis results, the internal factors of SMBA can be said to be the technologies for supporting small or medium businesses and those suitable for starting new businesses. Little's research stated that technologies in maturity period are in intense competition and efficiency and those in introductory period are in low competition and efficiency[15] (Little, 1981). According to the definition of R&D stage in this research, development research was defined as systematic research stage to produce a new product or device by utilizing basic or applied research and knowledge obtained from experience, or to practically improve an already produced or installed product.

Basic research was defined as an initially conducted theoretical or experimental research to obtain new knowledge about natural phenomena and observable objects, not aiming at special application or business. In terms of development research stage, SMBA showed that technologies in maturity period had significant correlation with commercialization, while RDA indicated that projects in introductory period and basic research stage had significant correlation with commercialization. The results demonstrated that projects of RDA focused on developing technology affiliated with universities or government and most projects were conducted with their cooperation as it concentrated more on agricultural technology research and education SMBA. These projects or technologies of RDA showed lower efficiency than those of SMBA.

The analysis results have the following implications. First of all, the research on improving commercialization requires consideration of commercialization from pre-project planning stage. If commercialization is the purpose of R&D, in the initial pre-project planning stage, selecting technologies' development research in maturity period for commercialization, not for basic or applied research, and proceeding with it will have an effect on improving commercialization.

Secondly, not only government support but also external cooperation is a vital factor in commercialization. Industry-university-institute collaboration has been considered as a key factor from the much preceding literature. This research results indicated that not only government support but also industry cooperation have a great effect on commercialization, if two ministries were all aiming at commercialization. However, concerns about external leakage of knowledge of technology and issues about application and range of technology ownership have continued therefore, an institutional measure for efficient Industry-university-institute collaboration needs to be strengthened.

Thirdly, commercialization needs to be considered in terms of quantity and quality. According to the comparison and analysis results of two ministries, the quantity of commercialization of RDA was approximately two times higher than SMBA. However, SMBA showed higher efficiency in terms of actual output compared input than that of RDA. Government needs to focus their investment to improve project efficiency with commercialization purpose.

This research has limitations including that two ministries were only selected in analysis and only correlation of factors was analyzed. However, it is expected to present a practical guideline in terms of policy making to improve commercialization for businesses with commercialization purpose and a direction for government support as it quantitatively analyzed actual national R&D data, unlike other researches.

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