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Analysis of the Performance of the Korean Government's R&D Subsidy for Small Businesses

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Table of Contents

Abstract

Investment in Research and Development (R&D) is one of the most significant governmental activities. Many countries including Korea continue the R&D investment in various fields such as defense, environment, and medical care. In addition, the Korean government has a plan to significantly expand R&D investment for small businesses because the growth of small businesses is considered as an important factor for economic development such as new job creation. Since the government budget is a finite resource in which various departments compete for the budget, the budget increase of a program can be justified when the government grants lead to better performance.

I analyzed the correlation between the performance indicators to assess the effects of the R&D subsidy program. Subjects of analysis are 347 companies that participated in the Technology Innovation Development of Small Businesses (TIDS) program in 2011. The reasons for using the data of the TIDS program are that the program has the largest budget and is often used by small businesses. Performance indicators are classified into inputs, outputs, and outcomes. The subsidy of the government is the important input. There are three types of outputs: whether to succeed in R&D for new products or processes, acquisition of patents, and commercialization of technology. Outcomes are the change in sales and the change in the number of employees.

As a result of analyzing the relationship between performance indicators, government grants, which is the most important explanatory variable, has a positive effect on the probability that small businesses succeed in R&D. It is statistically significant that companies which commercialized the technology developed are more likely to increase their sales.

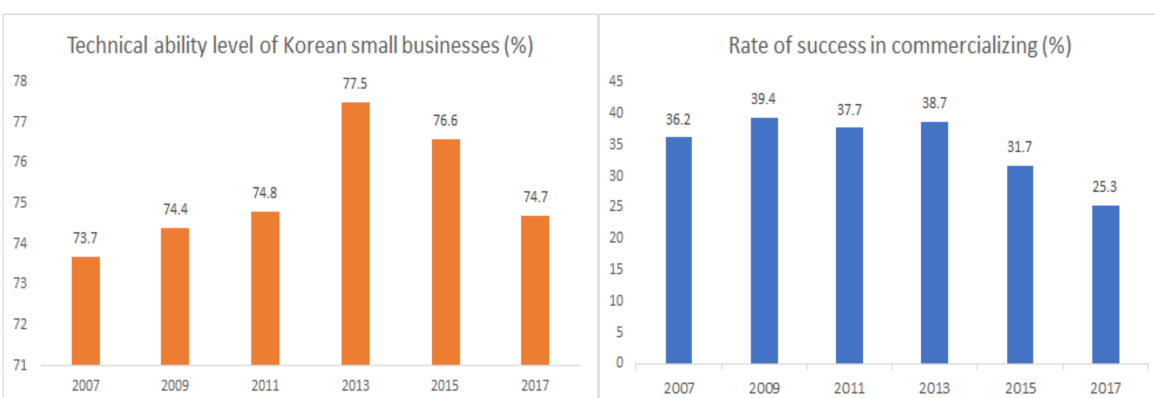
1. Introduction

Research and development (R&D) is considered an innovative activity that secures a company's competitiveness and promotes sustainable economic growth. Many studies have showed that R&D increased the competitiveness of companies. Gomulka (1990) and Fagerberg (1994) analyzed that R&D and national growth had mutually positive effects. R&D is regarded as a public good due to this characteristic, which is the rationale for government support of R&D (Arrow, 1962). Developed countries such as the United States, Germany, and Japan continue the government R&D investment in various fields such as defense, medical care, and the environment. However, small businesses lacking technology, manpower, and funds compared to large companies do not easily participate in government R&D support programs, so each country has developed policies to promote small business's participation in government R&D support programs. The Small Business Innovation Research (SBIR) program of the United States is a good example of a government R&D support program for small businesses. According to the Small Business Act and the policy directive of the SBIR program, federal agencies with extramural research budgets in excess of $100 million should allocate a certain percentage of the total extramural R&D budgets to small business.

The Korean government introduced the Small Business Innovation Research (KOSBIR) program in 1998 by benchmarking the U.S. SBIR program. This program has been operated by the Ministry of SMEs and Startups (MSS) which has the same role as the U.S. Small Business Administration. The KOSBIR program includes 13 government agencies in Korea, including the Ministry of Defense, the Ministry of Construction and Transportation, and the Ministry of Science and Technology. Similar to the U.S. SBIR program, the KOSBIR program requires that government agencies having R&D budgets reserve some percentage of their R&D budgets for a subsidy to small business. In addition, MSS introduced the R&D subsidy programs for only small business. While KOSBIR allocates some portion of the R&D budget to small businesses, MSS's R&D programs are only available to small businesses. The budget of the programs was expanded by 137 times from $7 million in 1998 to $960 million in 2017. During the presidential election of Korea in 2017, Jae-in Moon, who is the president of Korea, announced that it was one of his election pledges to double the budget of R&D programs for small business by 2021.

There are conflicting views on the performance of the Korean government's R&D support programs for small business. In the 2009 evaluation report, the Korea National Assembly Budget Office (NABO) concluded that the government's R&D support for small business had limited effects on enhancing the long-term competitiveness of small business (NABO has the same role as the U.S. Congressional Budget Office). In spite of the continuous support of the Korean government over the past 20 years, the technical level of small businesses did not improve much. According to the annual survey by MSS, the technical level of small businesses fell back in 2017. The technology level of small business is assessed by comparing with the world's top level of technology. The success rate of commercializing R&D results also was declining.

Figure 1. Technical ability level of Korean SMEs and Success rate of commercialization



On the other hand, the Korea Science and Technology Policy Institute (STEPI, 2017) showed that small businesses which received R&D subsidies from the government had positive results on performance indicators (sales growth rate, asset growth rate, and employee growth rate). These companies also achieved positive results in innovation capability indicators (R&D investment growth rate, R&D investment growth per employee). STEPI also argued that this analysis showed the importance of government R&D support for small business.

Despite contradictory views on the effects of government support, the Korean government has a plan to increase the budget of R&D subsidy to realize the election pledge of the current president. Government budgets are scarce resources. This budget increase for small business may be justified when the government subsidies lead to better performance of small business. It is necessary to assess the effectiveness of the program to verify the adequacy of the budget increase. According to Coccia (2001), measuring the performance of R&D is crucially important to decide the level of public funding for R&D.

2. Literature Review

The effects of government's R&D subsidies on business have been the subject of policy analysis. Prior research can be categorized into two areas according to the research questions: 1) Performance measures of R&D subsidy programs, and 2) Performance analysis of R&D subsidy programs.

1. Definitions of Performance Measures for the Government R&D Programs

According to Hill and Lynn (2016), performance measures are to provide a broad picture of an organization's efforts and results. Types of performance measures include inputs, outputs, outcomes, productivity, and impacts (pp. 438-439). Niven (2003) argued that performance measures were standards to evaluate and communicate performance against expected results.

Three types of performance measures have been used in practice: inputs, outputs, and outcomes. Inputs are the simplest elements to measure but provide limited information. Outputs are the results generated from the use of program inputs. Outcomes are the benefit received by stakeholders as a result of the organization's operations (pp. 186-189). Brown and Svenson (1988) also classified the R&D process of the firm into inputs, outputs, and outcomes. Inputs include research personnel, research equipment, research costs, and information. Outputs consist of patents, products, process improvements, publications, and knowledge. Outcomes include cost reduction, sales promotion, and product improvement. Cozzarin (2008) used input and output indicators to assess Canadian government R&D projects. In Cozzarin's (2008) study, inputs are program funding, financing constraints, project costs and investment efficiency. Outputs are company's sales, R&D success rates, papers and publications, product innovation, and patents.

The Korea Ministry of Science and Technology (2017), which oversees the overall R&D activities of the Korean government, classified the government R&D activities into basic, industrial, and public technologies and then provided standard performance measures that reflected the characteristics of each category. Table 1 shows this classification. Each agency is expected to evaluate the performance of R&D activity based on the standard performance indicators. R&D subsidy policy for small businesses belongs to the industrial technology, so the standard performance measures are patents, productivity, technology transactions, and commercialization. However, MSS, which enforces R&D subsidy policy for small businesses, has been using only easy-to-measure outputs when evaluating the performance: success of R&D, patents, and commercialization. The success of R&D is determined by assessing whether a company has reached the level of technology planned when the company was applying for a government subsidy. If only the easy-to-measure outputs are used, the government's policy performance may be evaluated inaccurately. This result could distort the efficient allocation of the budget.

Table 1. Classification of R&D Program in Korea and Performance Measures

Category	Purpose of government R&D	Performance measures	
		Indicators	Type
Basic technology	• Research activities without a specific purpose that enhance knowledge • Basic research with a specific purpose	Thesis	Output
		Prize or Reward	Output
Industrial technology	• Developing new technologies and products aimed at commercializing in the short-term • Development of core technology for the long-term	Patents	Output
		Commercialization	Output
		Technology transactions	Output
		Productivity	Outcome
		Market share	Outcome
Public technology	• Research activities to enhance public services such as energy • Research activities for improving quality of life such as the environment	Patents	Output
		Technology transactions	Output
		Productivity	Outcome
		Consumer satisfaction	Outcome
		Public welfare	Outcome

2. Effects of Government's R&D Subsidy

Previous studies have selected the government subsidy as a core input and then analyzed the relationships between government subsidy (input) and its performances (outputs and outcomes). Werner and Souder (1997) suggested that one approach for R&D measurement included both micro and macro level measurement techniques. Macro-level techniques focus on the impact of the R&D on society, which is related to the outcomes of R&D activities. Micro-level techniques focus on the impact on a firm.

2.1. Relationships between the Government Subsidy and Outputs

Griliches (1998, 2000) argued that there was a high correlation between productivity and the R&D activities of the business, and that there was also a positive correlation between R&D activities and patents. Howell (2017) analyzed the data on ranked applicants to the US Department of Energy's SBIR grant program. He showed that an early-stage award approximately doubled the probability that a firm received subsequent venture capital and had large, positive impacts on patenting and revenue. Based on the SBIR Program data, Wallsten (2000) concluded that the SBIR awards had no impact on the R&D activities of companies. On the other hand, Lerner (1999) argued that companies receiving government support through the SBIR program generally performed well in patent applications or sales.

One major research area has been whether a government subsidy can crowd out R&D investments of the private sector. Lach (2002) found evidence suggesting that the R&D subsidies granted by the Israeli government stimulated companies to finance R&D expenditures. For the small firms, a subsidy of one NIS (New Israeli Shekel) increases their R&D by about 11 NIS. This finding suggests that government R&D stimulates private investment instead of crowding it out. Regarding the effectiveness of the Korean government's R&D support for small businesses, Roh (2014) argued that the government 's R&D policy had complementary functions with private R&D investment. A 1% increase in government R&D funding led to the increase of company's R&D investment by 0.12% in the following year. An R&D subsidy may stimulate or inhibit private R&D investment depending on the countries and/or the industries considered (Capron and van Pottelsberghe, 2004). Based on the results of these preceding studies, the crowding-out effect of the government's R&D subsidies is ambiguous.

2.2. Relationships between Government Subsidies and Outcomes

Guillec and von Pottsberghe (2001) used panel data from 16 OECD countries for the long-term analysis of performance of R&D activities. They analyzed the impact of R&D that was invested from the public sector and the private sector on the productivity of countries. They argued that R&D activities in the public sector, as compared to the private sector, could play an important role in increasing national productivity. Roh (2014) analyzed the performance of Korea's R&D subsidy for small business by using output and outcome data: changes in employment, patent performance, commercial performance, and the success rate of R&D. He stated that while government R&D investment in small businesses had no effect on increasing employment, it had the effect of increasing corporate patent applications. Lee et al. (2009) used the difference-in-differences method to analyze the performance of Korean government R&D subsidies from 2000 to 2007. They showed that direct government funding for R&D improved the performance of small businesses on labor productivity. Roh and Song (2014) analyzed the 26,000 companies of the Korean government's R&D investment in small businesses during 2008-2013, and found that a government subsidy had a significant relationship with patent acquisition, but no statistically significant correlation with the performance such as sales and operating profit.

3. Summary

Previous studies show that the performance of government subsidies is ambiguous. The results vary depending on countries and programs. As previous studies have defined an R&D subsidy as input and analyzed the results, there are not enough studies to analyze R&D performance setting basic characteristics of companies such as age and number of researchers as inputs. It is necessary to analyze the policy performance by using basic characteristics of companies as explanatory variables. If the government finds the common characteristics of companies with good R&D performance, the government can change the policy to make it easier for the companies with these characteristics to receive R&D subsidies. To find out the common characteristics of companies with excellent R&D performance can be helpful to increase the policy performance. In addition, previous studies are lacking in analyzing the relationship between outputs and outcomes. The commercialization of the developed technology (output) can affect the sales of small businesses (outcome). Therefore, it is necessary to redefine the performance measures of R&D subsidies for small business, and then analyze the performance based on correlations between the measures in a phased manner (inputs → outputs → outcomes). This process can help to find representative measures and improve the quality of the evaluation, thus enhancing the policy performance. Table 2 shows the possible performance measures.

Table 2. Performance measures of R&D subsidy for small business

Inputs	Outputs and Outcomes
1. Inputs of R&D	1. Outputs
Subsidy by the government,	Success of R&D (Technology developed),
Investment of company,	Patents,
Number of researchers,	Commercialization
R&D periods.	
2. Characteristics of a company	2. Outcomes
Age of a company,	Increase in sales,
Sales / Assets / R&D intensity,	Increase in employees
Number of employees.	

3. Research Questions

This study will focus on the performance measures of the R&D subsidy program because the analysis of performance measures is essential for the performance analysis. The first step is to analyze the correlation between performance measures to confirm policy effects. The research questions related to this topic are as follows:

- Are there correlations between performance measures?
- How successful is the performance of the government R&D subsidy program?
- What are the improvements to the performance measures?

4. Research Design

1. Data Set

There are dozens of programs in Korea that support technology development of small business. Among these programs, the Technology Innovation Development of Small Businesses (TIDS) program is the most important because the program has the largest budget and is often used by small business. TIDS has a feature that supports small businesses to develop the technology they want without any special restrictions. TIDS started in 1997 with a budget of $30 million. By 2016, the program's budget had increased by 7.5 times with a budget of $226 million. TIDS subsidizes a small business up to $500,000 per year or 65% of the total cost for an R&D project. Table 3 shows the summary of the TIDS program.

Table3. Summary of the TIDS Program

Goal	Improve R&D capabilities of small businesses that lack competitiveness
Management	Ministry of SMEs and Startups (MSS) (MSS has the same role of U.S. Small Business Administration.)

History	• The program began in 1997 with a budget of $ 30 million. • By 2016, program budget had increased by 7.5 times with $ 226 million.
Subsidy	The maximum subsidy is $500,000 per year or 65% of the total cost for R&D.
Support period	Up to 24 months (2 years)
Selection	• The assessment committee comprising experts evaluates the technical and economic aspects of an R&D project at a ratio of 50:50. • The project is finally selected for a subsidy after a frontline employee of the MSS confirms the details submitted by a company.

* Data source: Ministry of SMEs and Startups (https://www.smtech.go.kr/front/sig/st/prjtIntro.do)

The R&D subsidy programs with specific purposes, such as the development of defense technologies, usually have restrictions. To develop only the technology required by the government is an example of the restrictions. The restrictions can lead to a problem of selection bias because it prevents small businesses from participating freely in R&D subsidy programs. Therefore, the TIDS program is suitable for analyzing the general characteristics of small businesses participating in the government's R&D subsidy programs. This study uses the data of small businesses that participated in the TIDS in 2011. The reason for choosing 2011 is that it takes several years to achieve the performance of R&D.

TIDS awarded R&D funding to 347 small businesses in 2011. Those firms are the subject of analysis in this paper. There are two ways of collecting the necessary data. First, basic data of small businesses are collected from the documents that small businesses submitted for applications in 2010. The performance data, which include all output measures and some outcome measures, can be gathered through the R&D Online Management System (http://www.smtech.go.kr). Small businesses receiving subsidies input basic data on the performance of R&D voluntarily into the system.

2. Dependent and Explanatory Variables

In order to analyze the performance of the R&D subsidy program, the first step is to define the performance measures. Considering the purposes of the study and features of the TIDS program, the explanatory variables are the inputs of R&D activities and the basic characteristics of a small business. The dependent variables are outputs and outcomes. Data on the sales and employment of companies participating in the TIDS program are surveyed for four years from 2013 to 2016 after the completion of the two-year technology development (2011 ~ 2012). There are reasons to use the four-year outcome data after two years of governmental support. First, the TIDS program supports governmental subsidies for R&D projects that small businesses can develop within two years. Second, it usually takes time to get outcomes because outcomes are the benefit received by stakeholders as a result of the organization's operations. The performance measures of the TIDS program can be as summarized in Table 4.

Table 4. Explanatory and Dependent Variables

Explanatory variables	Dependent variables
1. Inputs of R&D	1. Outputs
Subsidy by the government	Success of R&D (Technology Developed)
Investment of a company	Patent
Number of researchers	Commercialization
R&D periods (month)	
2. Basic Characteristics of a company	2. Outcomes
Age of a company	Change of sales
Average sales per year	Change of the number of employees
Number of employees	
Average assets per year	
Total R&D investment of a company	

The Ministry of SMEs and Startups (MSS) of Korea has used officially three outputs (success of R&D, patents acquisition, and commercialization) as performance indicators for the TIDS program. The success of R&D is judged by whether a small business has developed the technology they proposed when applying for government subsidies. The R&D tasks proposed by small businesses usually include the development of new products or processes or the improvement of existing products or processes. TIDS supports small businesses to develop technologies within two years. After two years of R&D, the MSS forms an expert committee including professors and patent attorneys and then evaluates the success of R&D. The difficulty of developing technology in the TIDS program is not high. According to Table 3, the R&D success rate was 93.1% in 2011. MSS explained that the reason for the high success rate was a characteristic of the program. If a company fails to develop a technology, the MSS evaluates the R&D process of the company. When determining that the process is inadequate, the MSS can take back up to 100% of the government subsidy. This aspect of the TIDS program may encourage small businesses to apply for the subsidies with an R&D project that is likely to be easy to develop. The commercialization rate of the developed technology is 53.1% of responding companies. The percentage of acquisition of patents is 24% of respondents.

Table 5. Summary of variables

Variables	Measurement	Obs.	Mean	S.D.	Min.	Max.
Inputs						
subsidy	subsidy of government ($1000)	347	370.2	74.8	128	480
projectfund	investment of business ($1000)	347	136.7	48.4	43	630
researcher	number of researchers	347	12.1	4.5	4	42
periodrnd	period of R&D (month)	347	23.3	2.9	12	30
age	age of a business (month)	347	124.1	90.6	6	740

employee11	number of employees in 2011	315	55.5	65.1	2	438
sales11	sales in 2011 ($1000)	339	16762.7	32573.5	29	339509
assets11	assets in 2011 ($1000)	339	17157.1	30147.9	231	244850
totalrnd11	total R&D investment in 2011($1000)	313	714.3	1021.0	5	9039
Outputs						
successrnd	success in R&D = 1, fail = 0	347	0.931	0.254	0	1
patent	patent = 1, no patent = 0	275	0.240	0.428	0	1
commercial	success = 1, fail = 0	275	0.531	0.500	0	1
Outcomes						
sales13	sales in 2013 ($1000)	337	18148.1	40792.9	2	603278
sales14	sales in 2014 ($1000)	337	18649.3	36770.8	4	500434
sales15	sales in 2015 ($1000)	336	18992.9	34246.6	12	398884
sales16	sales in 2016 ($1000)	331	20321.4	36992.7	6	349412
employee13	number of employees in 2013	169	69.8	81.2	6	423
employee14	number of employees in 2014	172	79.3	88.7	5	420
employee15	number of employees in 2015	177	80.8	90.1	2	524
employee16	number of employees in 2016	199	72.6	86.4	3	453

3. Analysis Model

Since all outputs are binary variables, probit model is suitable to estimate the probability that an observation with particular characteristics will fall into a specific category.

- Response probability in a probit model:

  $P(y = 1 \mid \mathbf{x}) = \Phi(\beta_0 + \mathbf{x}\boldsymbol{\beta})$,

  y is outputs (success of R&D, patent acquisition, and commercialization) and **x** is inputs.

  $\Phi(z)$ is the standard normal cumulative distribution function.

The second step is to analyze the effects of outputs on outcomes. Changes in the company's sales and employment are influenced by various economic factors. It is possible to apply a difference-in-differences (DID) model to eliminate the influence of factors that are difficult to measure if data on an untreated control group are available and there are statistically equal pre-treatment trends. In this case no data are available for the untreated controls. A regression is estimated comparing pre-treatment and post-treatment outcomes for treated companies. The regression model is to evaluate the impacts of commercialization or patents acquisition after the success of R&D. The difference in outcomes between 2011 and the next four years (2013-2016) can be estimated by the regression model. The year of 2012 when small business was developing technology is excluded from the regression model.

- Model for analyzing the impact on sales:

  $sales_{t2} - sales_{t1} = a + b_1$ commercial $+ b_2$ patent $+ b_3$ commercial $\times$ patent $+ e$,

  $sales_{t2}$ is the total sales per year from 2013 to 2016 and $sales_{t1}$ is the total sales in 2011.

- Model for analyzing the impact on number of employees:

  $employee_{t2} - employee_{t1} = a + b_1$ commercial $+ b_2$ patent $+ b_3$ commercial $\times$ patent $+ e$,

  $employee_{t2}$ is the number of employees per year from 2013 to 2016,

  and $employee_{t1}$ is the number of employees in 2011.

In the model, the coefficient b_1 is the difference of change in the sales or change in the number of employees between the companies that successfully commercialized the developed technology and those that failed. The coefficient b_2 means the difference of change in the sales or change in the number of employees between patented and non-patented companies. The coefficient b_3 means the difference of change in the sales or change in the number of employees between companies that succeeded both in commercialization and patent acquisition and those that did not, beyond the direct effects of each alone.

According to the results of the t-test, there is no statistically significant difference in average sales and average employee in 2011 between companies that succeeded in the commercialization of technologies and those who did not. Whether companies acquired patents or not also shows the same result. There is no statistically significant difference between the two groups in terms of sales and employment in 2011 when R&D began. Therefore, it is possible to compare the R&D outcomes, which include the change in sales and the change in the number of employees.

Table 6. Results of t-test

Types	Groups of company	Obs.	mean	s.e.	d.f.	t	p-value
Sales in 2011	No commercialization	125	17535.4	2683.4	267	0.745	0.4569
	Commercialization	144	15037.5	2081.8			
Employee in 2011	No commercialization	115	58.756	6.239	248	0.822	0.4118
	Commercialization	135	52.022	5.376			
Sales in 2011	No patent	203	17472.1	2118.8	267	1.339	0.1817
	Patent	66	12279.9	1922.9			
Employee in 2011	No patent	188	56.686	4.691	248	0.667	0.5049
	Patent	62	50.370	8.298			

5. Results and Findings

1. Relationships between Inputs and Outputs of the TIDS Program

According to the results of Probit estimation, some inputs have a statistically significant relationship with outputs. First, the government subsidy, which is estimated to be statistically significant, has a positive effect on the probability that small businesses succeed in R&D. When government subsidy increases by 1,000 units ($1,000,000), the probability of success in R&D is increased by 0.6254. The time taken to develop the technology has no statistically significant effect on the probability of success in R&D. The estimation results are summarized in Table 7.

Table 7. Probit estimation 1 (Dependent Variable: Success of R&D)

Independent Variables	Estimates	Average Marginal Effects
Subsidy ($1,000,000)	7.4440*** (2.0109)	0.6254** (0.2522)
Projectfund ($1,000,000)	-0.5498 (2.5308)	-0.0462 (0.2129)
Researcher (1,000 researchers)	-1.0654 (30.5958)	-0.0895 (2.5695)
Periodrnd (1 month)	-0.2762 (0.1864)	-0.0232** (0.0117)
Age (1,000 months)	0.6296 (1.8692)	0.0529 (0.1606)
Employee11 (1000 employees)	-1.8921 (3.6657)	-0.1589 (0.3048)
Sales11 ($100,000,000)	-0.6488 (1.6149)	-0.0545 (0.1367)
Assets11 ($100,000,000)	2.9114 (2.5122)	0.2446 (0.1982)
Totalrnd11 ($100,000,000)	-7.2920 (21.3250)	-0.6127 (1.7757)
Constant	5.2242 (4.4132)	
Log-likelihood value	-62.7339	

1) *** p<0.01, ** p<0.05, * p<0.1, 2) ( ): Standard error
3) Some Coefficients are rescaled by 1,000 or by 100,000 to be read easily.

- By 1,000: Subsidy, Project fund, Number of Researchers and Employees, and Age
- By 100,000: Sales, Assets, and Total R&D Funding in 2011

The second is the relationship between the acquisition of patents by small business and input indicators after R&D is over. The effect of the annual sales volume of firms in 2011 is statistically significant, but the average marginal effect of sales in 2011 is very small. The acquisition of the patent is decreased by 0.879 when the sales in 2011 are increased by 100,000 units ($100,000,000). The effect of the government subsidy is not statistically significant. The estimation results are summarized in the Table 8.

Table 8. Probit estimation 2 (Dependent Variable: Acquisition of Patent)

Independent Variables	Estimates	Average Marginal Effects
Subsidy ($1,000,000)	0.2850 (2.4883)	0.0872 (0.7611)
Projectfund ($1,000,000)	-6.9722 (5.3332)	-2.1353 (1.6026)
Researcher (1,000 researchers)	-23.6606 (22.4142)	-7.2465 (6.8610)
Periodrnd (1 month)	0.0278 (0.0491)	0.0085 (0.0150)
Age (1,000 months)	1.4669 (1.2548)	0.4492 (0.3827)
Employee11 (1000 employees)	2.7728 (2.9174)	0.8492 (0.8844)
Sales11 ($100,000,000)	-2.8702** (1.4056)	0.8790** (0.4124)
Assets11 ($100,000,000)	1.4058 (1.0503)	0.4305 (0.3168)
Totalrnd11 ($100,000,000)	-14.3598 (15.3405)	-4.3979 (4.6671)
Constant	-0.2255 (0.9728)	

Log-likelihood value	-122.4492	

1) *** p<0.01, ** p<0.05, * p<0.1,   2) ( ): Standard error
3) Some Coefficients are rescaled by 1,000 or by 100,000 to be read easily.

- By 1,000: Subsidy, Project fund, Number of Researchers and Employees, and Age
- By 100,000: Sales, Assets, and Total R&D Funding in 2011

The following is the effect of inputs on the probability of commercialization of the developed technology. The number of researchers has a negative influence on the possibility of commercialization. When the number of researchers increases by one, the possibility of commercialization decreases by 0.0226. The age of the firm is also statistically significant at the 90% confidence level. When the age of the firm increases by one month, the possibility of commercialization decreases by 0.0008. The effect of government subsidy is not statistically significant. The estimation results are summarized in the Table 9. Lastly, the effect of R&D funding by small business and the effect of the number of employees are not statistically significant. The basic characteristics of a company have no effects on the outputs.

Table 9. Probit estimation 3 (Dependent Variable: Success of Commercialization)

Independent Variables	Estimates	Average Marginal Effects
Subsidy ($1,000,000)	1.9841 (1.7764)	0.7847 (0.7026)
Projectfund ($1,000,000)	0.2110 (2.1581)	0.0834 (0.8535)
Researcher (1,000 researchers)	-57.3925*** (21.0658)	-22.6981*** (8.3333)
Periodrnd (1 month)	-0.0080 (0.0462)	-0.0031 (0.0183)
Age (1,000 months)	-2.1654* (1.1599)	-0.8564* (0.4587)

Employee11 (1000 employees)	-0.2561 (2.5811)	-0.1012 (1.0208)
Sales11 ($100,000,000)	-0.7509 (0.7130)	-0.2970 (0.2820)
Assets11 ($100,000,000)	1.0292 (0.8972)	0.4070 (0.3548)
Totalrnd11 ($100,000,000)	-5.6011 (10.9012)	-2.2151 (4.3110)
Constant	0.5294 (0.9048)	
Log-likelihood value	-147.4966	

1) *** p<0.01, ** p<0.05, * p<0.1, 2) ( ): Standard error
3) Some Coefficients are rescaled by 1,000 or by 100,000 to be read easily.

- By 1,000: Subsidy, Project fund, Number of Researchers and Employees, and Age
- By 100,000: Sales, Assets, and Total R&D Funding in 2011

2. Relationships between Outputs and Outcomes of the TIDS Program

According to the results of regression model estimation, the acquisition of patents is evaluated to have no statistically significant effect on the outcomes of R&D: an increase in sales and an increase in the number of employees. Successful commercialization of the developed technology has no statistically significant effect on the increase in the number of employed persons. The effects of the interaction term (commercialization × patent) in the regression model are also not statistically significant.

However, there is statistically significant evidence that the increase in sales of companies succeeding in commercialization is greater than the increase in sales of the others in 2014 and in 2015. In 2014, which is the second year of successful commercialization after technology development, commercialization has a positive effect on sales change and the estimation is statistically significant at the 90% confidence level. Companies that have succeeded in commercializing have higher sales growth than those that have not. The difference in sales per year is about $ 3.3 million dollars. In 2015, there is also a positive correlation between the change in sales and commercialization at the 99% confidence level. The difference in sales per year is about $5.7 million. In summary, the commercialization of the developed technology can have a positive effect on the change in the sales of the company. There is no evidence of correlations between commercialization and changes in the number of employees. The estimation results are summarized in the Table 10.

Table 10. Results of Regression Model Estimation
Table 10-A. Dependent Variable: Change in Sales

Independent variables	Dependent variables			
	Sales13-Sales11	Sales14-Sales11	Sales15-Sales11	Sales16-Sales11
Commercial	-24.13 (1570.08)	3277.8* (1808.12)	5679.8*** (2168.16)	3237.0 (2579.23)
Patent	-75.19 (2532.05)	2697.7 (2911.31)	2446.5 (3491.01)	1553.6 (4132.62)
Commer × Patent	-432.8 (3251.80)	-4109.0 (3737.40)	-6187.3 (4481.60)	-4633.6 (5298.82)
Constant	633.4 (1118.47)	-380.8 (1291.26)	-941.4 (1548.38)	1287.7 (1855.91)
Observation	267	266	266	263
R-squared	0.0003	0.0129	0.026	0.007

1) *** p<0.01, ** p<0.05, * p<0.1   2) ( ): Standard error

Table 10-B. Dependent Variable: Change in Employees

Independent variables	Dependent variables			
	Employee13 - Employee11	Employee14 - Employee11	Employee15 - Employee11	Employee16 - Employee11
Commercial	4.6518 (5.9887)	-2.7643 (8.7464)	2.5007 (7.8006)	4.2493 (8.4391)
Patent	-5.2277 (9.6397)	-10.26 (12.6033)	-2.9677 (11.8262)	-2.4902 (12.2103)
Commer × Patent	-2.4494 (12.2942)	2.3825 (16.7927)	0.0641 (15.5054)	-6.2365 (16.2999)
Constant	6.3111 (4.4230)	15.46** (6.0544)	8.0392 (5.4884)	11.6078 (6.1051)
Observation	132	133	137	147
R-squared	0.0137	0.0102	0.0019	0.0056

1) *** p<0.01, ** p<0.05, * p<0.1   2) ( ): Standard error

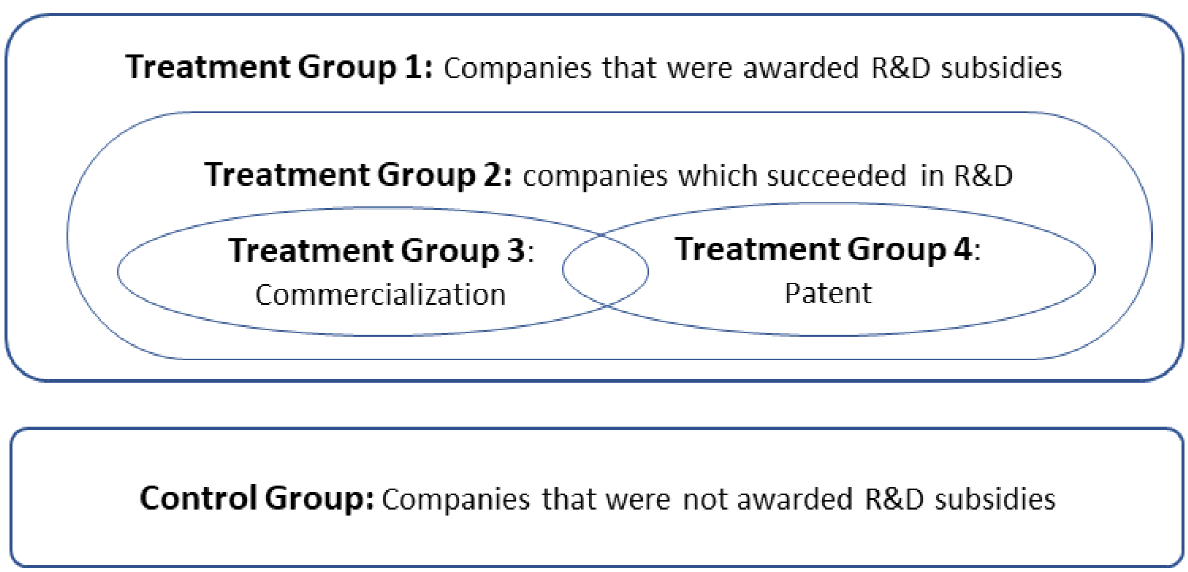
6. Limitations

The collection of data has caused the limitations. First, in order to evaluate the effect of government subsidies on R&D, it is necessary to classify a control group and treatment groups as shown in Figure 3. The effect of government subsidies can be assessed by comparing outcomes (changes in sales and changes in the number of employees) between the control group and the treatment group 1. The control group is a group that applied for government subsidies in 2011 but did not receive subsidies. In fact, there are about 1,000 small businesses in the control group. The treatment group 1 is a group that they received subsidies. The reason for the difficulty of data collection is because small businesses in the control group were not obliged to submit relevant data because they did not receive government subsidies.

The difficulty of data collection affected the design of the evaluation model. Instead of comparing the control group to the treatment group 1, the evaluation model is to compare the performance among the groups in treatment group 1. This model can compare the effects of the commercialization of technologies developed and patent acquisition. Therefore, the model may evaluate the effect of government subsidies partially because it assesses the effect of developing new products or processes. In order to evaluate fully the effect of government subsidies, additional research is needed after collecting data from the control group.

The second limitation with regard to data collection is the missing data problem. Table 3 shows that there are about 50% missing data in the number of employees by year. There are also 21% missing data in patent acquisition and commercialization. The missing data are limiting factors for accurate evaluation.

Figure 2. Classification of the Evaluation Group



7. Conclusions

R&D investment is one of the most significant public activities and it is generally considered to be a useful way to spend public funds. Based on this concept, many developed countries continue the R&D investment in various fields such as defense and medical care. The Korean government has also continued to invest in R&D and has a plan to significantly expand R&D investment for small businesses. However, the government budget, which is based on taxation, is a scarce resource so that the budget increase of a program can only be justified when the government grants lead to better performance. Based on this perception, I analyzed quantitatively the performance of TIDS program that is an important R&D subsidy program for small business in Korea.

Performance indicators, which are used in the R&D subsidy program, are classified into inputs, outputs, and outcomes according to the logic model. Subsidy of the government is the most significant input. There are three types of outputs: whether the firm succeeds in R&D for new products or processes, acquisition of patents, and commercialization of technology. The R&D success rate was 93.1% in 2011. The success rate of commercialization is 53.1% of responding companies. The percentage of acquisition of patent is 24% of respondents. As R&D subsidies are granted to small businesses, the increase in sales and number of employees can be the proper measures for the outcome.

The analysis of the relationship between inputs and outputs reveals that receiving a government grant, which is the most important explanatory variable, has a positive effect on the probability that small businesses succeed in R&D. The general characteristics of firms such as age, number of employees, and assets do not have a significant impact on outputs of R&D. In order to understand the characteristics of firms that affect R&D, additional research is needed to analyze the performance by using the specific characteristics of firms related to R&D such as career of researchers and the presence of research institute.

As a result of analyzing the correlation between outputs and outcomes (business performance) of the TIDS program, it is statistically significant that success in commercialization of R&D increases companies' sales. Companies that have succeeded in the commercialization of technology developed are more likely to increase their sales.

In summary, government subsidies for R&D in small businesses have some positive effects on outputs. In addition, it is estimated that the sales of the companies that successfully commercialize the developed technology increase. However, due to the limitations of data collection, the effect of government subsidies on the performance of small businesses could not be analyzed. This part needs further study. The most significant performance indicator in the TIDS program is the commercialization of R&D. To improve policy performance, MSS should modify the TIDS program to increase the commercialization rate.

Table 11. Summary of Important Results

Independent Variables	Dependent Variables	Results
Government Subsidy	R&D Success	Positive effect
	Patents	No effect
	Commercialization	No effect
Patents	Sales	No effect
	Employment	No effect
Commercialization	Sales	Positive effect
	Employment	No effect

References

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. *The rate and direction of inventive activity*. Princeton, NJ: Princeton University, 609-625.

Bae, K. (2016). Performance indicators and improvement of performance management for enterprise R&D support policies. *ISSUE PAPER*, 2016-09. Seoul, Korea: Korea Institute of S&T Evaluation and Planning.

Brown, M. & Svenson, R. (1988). Measuring R&D Productivity. *Research Technology Management*, 31, 11-15.

Capron, H. & van Pottelsberghe, B. (2004). Public support to business R&D: A survey and some new quantitative evidence. *OECD STI Working Paper*.

Coccia, M. (2001). A basic model for evaluating R&D performance: theory and application in Italy. *R&D Management*, 31(4), 453-464.

Cozzarin, B. P. (2008). Data and the measurement of R&D program impacts. *Evaluation and Program planning*, 31(3), 284-298.

Edison, T. R. (2010). *Estimation of the DOD SBIR program treatment effect*. Santa Monica, CA: RAND Corporation.

Fagerberg, J. (1994). Technology and international differences in growth rates. *Journal of Economic Literature*, 32, 1147-1175.

Gomulka, S. (1990). *The theory of technological change and economic growth*. New York, NY: Routledge.

Griliches, Z. (1998). *R&D and Productivity: The Econometric Evidence*. Chicago, IL: Univ. of Chicago Press (for NBER).

Griliches, Z. (2000). *R&D, Education, and Productivity: A Retrospective*, Cambridge, MA: Harvard University Press.

Guellec, D & van Pottelsberghe, B. (2001). R&D and productivity growth: panel data analysis of 16 OECD countries. *OECD STI Working Paper*.

Hill, C. J. & Lynn, L. E. Jr. (2016). *Public Management: Thinking and Acting in Three Dimensions*. Los Angeles, CA: SAGE.

Howell, S. T. (2017). Financing innovation: evidence from R&D grants. *American Economic Review*, 107(4), 1136-1164.

Korea Ministry of Science and Technology (2017). *2017 Survey report of national research and development projects*. Seoul, Korea: Author.

Lee, Y., Kim, K., & Shin, B. (2009). An empirical analysis on effects of technological development subsidy on firm productivity. *The e-Business Studies*, 10(4), 367-389.

Lerner, J. (1999). The government as venture capitalist: The long-run impact of the SBIR program. *The Journal of Business*, 72(3), 285-318

National Assembly Budget Office (2009). *Evaluation of SME technology innovation development project*. Seoul, Korea: Author.

Niven, P. (2003). *Balanced Scorecard Step-by-Step for Government and Nonprofit Agencies*. Hoboken, NJ: John Wiley & Sons.

Roh, Y. & Song, C. (2014). A study on the performance of R&D project supported by SMEs. *Korean Industrial Economics Research*, 429-457.

Roh, Y. (2014). *Analysis of the effects of the R&D projects for small businesses*. Seoul, Korea: National Assembly.

Science and Technology Policy Institute (2017). Analysis of status and performance of R&D

support for SMEs. *STEPI Insight*, 211.

Small Business Administration (2014). *Small Business Innovation Research (SBIR) Program Policy Directive*. Washington D.C.: Author, 3-7.

Wallsten, S. J. (2000). The effects of government-industry R&D programs on private R&D: The case of the small business innovation research program. *The Rand Journal of Economics*, 31(1), 82-100.

Werner, B.M. & Souder, W.E. (1997). Measuring R&D performance-state of the art. *Research and Technology Management*, 40(2), 34-42.