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**Research Report**

## Government R&D Support for SMEs: Policy Effects and Improvement Measures

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**KDI FOCUS** | Analysis on critical pending issues of the Korean economy to enhance public understanding of the economy and provide useful policy alternatives.

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## Government R&D Support for SMEs: Policy Effects and Improvement Measures\*

Sungho Lee, Fellow at KDI

**“The government’s R&D grant for SMEs has risen to 3 trillion won a year, placing Korea second among OECD nations. Indeed, analysis revealed that government support has not only expanded corporate R&D investment and registration of intellectual property rights but has also increased investment in tangible and human assets and marketing. However, there has been a lack of improvements found in the value added, sales and operating profit because the recipient selection system, which relies solely on the qualitative assessments of technology experts was ineffective. Nevertheless, if a predictive model was properly applied to the system, the causal effect on the value added could increase by more than two fold. Accordingly, to develop such a model, it is important to focus on the economic performance rather than the technical achievements. Also, more policy experiments should be conducted on small firms and a phased approach for R&D financing should be adopted (① grant → ② equity investment → ③ loan).”**

### I . Introduction

Forty percent of the entire national annual R&D budget (19 trillion won) is allocated for economic growth—including industrial and infrastructure development. In 2016, 3 trillion of the 8.1 trillion won was earmarked for the innovation of SMEs in the form of R&D grants, making Korea the second biggest spender next to the US among OECD members, ahead of

\* Based on Lee, Sungho, *Predictive Models that Select the Recipients of R&D Grants to Maximize the Growths of SMEs*, Policy Study 2017-12, Korea Development Institute, 2017 (in Korean).

**<Table 1> International Comparison of Total Corporate R&D Investment and Government-funded R&D Costs by Firm Size**

(\$1 million, PPP exchange rate)

Number of employees	Korea (201)	US (2011)	Japan (2013)	Germany (2013)	France (2013)
1-49	6,033 (914)	21,842 (2,066)	1,135 (49)	2,448 (544)	4,292 (492)
50-249	5,955 (662)	21,996 (1,515)	4,620 (99)	4,230 (499)	4,881 (261)
SME subtotal	11,988 (1,576)	43,838 (3,581)	5,755 (148)	6,678 (1,043)	9,173 (753)
250-	41,442 (1,384)	250,255 (27,730)	117,776 (1,162)	62,235 (1,272)	28,331 (2,281)
Total	53,430 (2,961)	294,092 (31,630)	123,531 (1,310)	68,914 (2,316)	37,503 (3,035)

*Note:* Figures in parentheses denote government-funded R&D costs.

*Source:* Main Science and Technology Indicators (OECD Stat webpage). Cited from Park *et al.* (2016) p.24–25.

**Korea's R&D subsidy for SMEs has risen to approx. 3 trillion won a year, making Korea the second largest spender among OECD nations.**

Germany and Japan in absolute amount. And, thanks to the government's direct grants and indirect tax benefits, the yearly R&D investment of Korean SMEs exceeded 13 trillion won in the same year (36,026 affiliated research institutes). Korea ranks fourth, or fifth when China is included, in total corporate R&D and second<sup>1)</sup> in SME R&D among OECD nations as shown in <Table 1>. In particular, small firms with less than 50 employees, including start-ups, were found to invest more actively in R&D than medium-sized firms.<sup>2)</sup>

Preceding literature on the performance evaluation of R&D support projects have mainly focused on how support contributes to increasing corporate R&D investment and intellectual property rights, and the majority of outcomes have been positive. However, with the exception of Oh and Kim (2017), very few studies deal with the economic gains of R&D support. Indeed, with the government's R&D grant for SMEs at the 3 trillion won mark, this study attempts to comprehensively assess government support projects and seek ways to enhance their effectiveness.

## II . Government R&D Support Projects for SMEs

**The SBIR, the main R&D support program for SMEs in the US, is structured in three phases.**

The Small Business Innovation Research (SBIR) program is the main R&D support program for SMEs in the US. Federal agencies with budgets in an excess of \$100 million for extramural R&D are obliged to allocate at least 3.2% to the program. The support is provided in three phases: Phase I is the proof-of-concept stage and a total of \$0.10-0.15 million is provided for 6-9 months; Phase II supports the subsequent full-scale R&D with funds reaching \$1 million for a period of 24 months and; Phase III assists SMEs with commercialization through investment and funding from financial institutions in the private sector. In 2015, the SBIR program distributed about \$2.5 billion via 11 departments.

1) China has rapidly expanded R&D investment and risen to the world's second largest (no statistics available on SME R&D).

2) Largely thanks to the government's Fund of Funds, Korea's venture capital investment to GDP ratio ascended to 0.13% in 2015, standing below the US (0.33%) and China (0.24%) but far higher than Japan, Germany and France (approx. 0.03 %) (Park *et al.*, 2016).

Edison (2010) examined 1,460 companies applying for the US Department of Defense's (DOD) SBIR in 2003 and found a significant causal effect that increased the sales of recipients by \$0.15 million during the following year (\$0.37 million in 2004-2006). In addition, Howell (2017) analyzed the earnings of 5,021 companies applying for the US Department of Energy's (DOE) SBIR in 1995-2013 and confirmed that the grant awarded during Phase I increased the average 10% probability of venture capital funding by +10%p and \$2 million sales by \$1.3-\$1.7 million. The results also revealed that the increases were not owed to the effects from government certification but to the effects from proof-of-concept demonstrated via prototypes. Moreover, the increase in venture capital funding was particularly strong among firms without patents and young startups of less than two years (+6%p and +14%p). On the other hand, the extensive grants given during Phase II had little economic impact. Accordingly, Howell (2017) concluded that rather than offering large long-term funding to a few medium-sized firms, it would be more effective to award small lump sums to numerous small-sized firms. Germany and Finland operate similar programs, providing small grants and research consulting services to such firms and startups who lack R&D experience. Most R&D support programs in advanced economies have transparent and convenient online management systems that accommodate free competition for bottom-up research designs.

Based on the SBIR, the Korean government established the Korea Small Business Innovation Research (KOSBIR) program in 1998 and has steadily increased the budget since. Indeed, the expenditure for SME-operated government R&D projects recorded 2,897 billion won in 2016,<sup>3)</sup> which is equivalent to 15.2% of the government's total R&D investment and similar to the US SBIR's total support. According to the National Science and Technology Knowledge Information Service (NTIS) database, which integrates the management of all government R&D projects, among the 30,448 R&D projects awarded to firms in 2010-2014, the median fund amount was 200 million won while the top 20% marked 525 million-54.7 billion won and the bottom 20% was less than 100 million won. In the US, the number of Phase I projects (about \$0.10 million per project) outnumbered Phase II projects by two to even three times. But in Korea, about 80% of projects were funded with over 100 million won per project—this implies that there is a strong tendency to omit the initial proof-of-concept stage and begin with full-fledged support.

The evaluation of R&D support projects are dependent on patents and publications. And, due to their strong commitment in acquiring more patents, patent applications for SMEs have continued to soar, rising from 34,547 in 2013 to 46,813 in 2016.<sup>4)</sup> That for large enterprises, on the other hand, have declined from 48,045 to 38,800 over the same period following a shift in the evaluation focus of R&D divisions to the creation of economic value after it was deemed that practices such as stockpiling unused patents to simply demonstrate technological prowess was a waste of financial (patent application and renewal) and research resources.

The US case shows that the small lump sum grants for a large number of small firms is more effective than large funds for a few mid-sized firms.

3) Ministry of Science and ICT · Korea Institute of Science & Technology Evaluation and Planning, *2016 National R&D Project Report and Analysis*, 2017 (in Korean).

4) Korea Intellectual Property Office, *Intellectual Property Statistics FOCUS*, 2014, 2017 (in Korean).

### III. Comparison between Recipients and Non-recipients

The Korean government's corporate R&D support mostly targets medium-sized development activities, not small-scaled exploratory research.

To analyze the economic effects of government support programs, this study used the Korea Enterprise Data (KED) (2010-2015), which contains information on enterprises that is linked to 70% or 21,265 cases in the NTIS. Research subjects were limited to incorporated enterprises with more than 10 employees, and the 2010-2015 financial performance of a total of 212,245 firms were analyzed—of which 165,023 small-sized firms and 42,770 medium-sized firms were the main focus of the analysis.

Current corporate R&D support which is evaluated by the number of registered patents and publications must be reformed.

Based on the financial data, this study extracted ten performance indicators regarding the following three aspects: operating performance (value added, sales and operating profit), financing (debt and equity) and capabilities/assets.<sup>5)</sup> The value added is the most comprehensive indicator as it covers all values that are distributed to various stakeholders, including employees (labor cost), shareholders (dividend), government (taxes and dues), creditors (interest), and firms (net profits + depreciation cost). Additionally, despite the significance of the economies of scale in the past, the scalability of intangible assets has grown in importance as shown by Uber and Airbnb. Thus, in terms of performance indicators for capabilities/assets, this study used R&D investment, IP rights registration and marketing investment in conjunction with tangible assets and human capital investment.<sup>6)</sup>

The scalability of intangible assets is as important as the economies of scale of tangible assets.

<Table 2> shows that recipients considerably outperformed non-recipients on average in most indicators including operations, financing and capabilities/assets when they receive subsidies. The gap is statistically significant, and widens further when all samples of middle-standing and large enterprises are included. And, in operating profit and R&D investment indicators, the average value widens over 20 fold. Two to three years after the support, however, there is a visible reverse in this trend, except in IP rights registration, and there is even negative growths in operating profit and R&D investment.<sup>7)</sup> When large enterprises are included in the comparison, the negative growth can also be observed in the value added and marketing investment.

<Table 2> Basic SME Statistics Comparison

(1 million won)

Variables		Non-recipient SMEs (control group: 670,760)		Recipient SMEs (experimental group: 18,980)	
		Average	Standard deviation	Average	Standard deviation
Basic	Firm age	9.10	8.26	10.72	7.80
	IPO ratio	0.13	0.33	0.36	0.48
	Ratio of government-certified venture firms	0.10	0.30	0.57	0.50

5) The distribution of corporate performance tends to skew to the right influenced by large firms. As such, logarithmic transformation of the raw data was made while the raw data for the value added, operating profit and equity was used as they were since many of them were negative.

6) Based on financial statements: tangible asset data was used as tangible asset; the sum of labor-related costs, welfare benefits, education and training costs and stock compensation was used as the proxy variable of human capital investment; the sum of R&D expenditure in income statement and manufacturing cost statement and increments of intangible asset development costs was used as intellectual property investment; and the sum of advertising costs, sales promotion costs, entertainment expenses and overseas marketing expenses was used as the proxy variables for relational assets.

7) As for equity financing, recipients posted a larger increment but smaller increase rate.

Variables		Non-recipient SMEs (control group: 670,760)		Recipient SMEs (experimental group: 18,980)	
		Average	Standard deviation	Average	Standard deviation
Performance	Value added	1,389	19,100	3,008	5,988
	Increment ( $\Delta_{t+2}$ )	195	26,400	43	9,792
	Increment ( $\Delta_{t+3}$ )	330	31,200	163	10,400
	Sales	6,733	21,900	13,600	30,500
	Increment ( $\Delta_{t+2}$ )	0.36	2.11	0.13	1.06
	Increment ( $\Delta_{t+3}$ )	0.41	2.16	0.17	1.09
	Operating profit	255	2,826	559	3,105
	Increment ( $\Delta_{t+2}$ )	8	3,067	-155	3,639
	Increment ( $\Delta_{t+3}$ )	8	3,134	-203	3,969
Financing	Debt	4,030	32,100	7,820	17,400
	Increase rate ( $\Delta_{t+2}$ )	0.32	1.25	0.22	0.66
	Increase rate ( $\Delta_{t+3}$ )	0.42	1.31	0.29	0.75
	Equity	2,360	18,500	7,505	20,900
	Increment ( $\Delta_{t+2}$ )	447	7,077	1,046	13,300
	Increment ( $\Delta_{t+3}$ )	750	8,821	1,758	14,600
Competence assets	R&D investment	64	1,377	741	1,718
	Increase rate ( $\Delta_{t+2}$ )	0.22	4.23	-0.77	5.36
	Increase rate ( $\Delta_{t+3}$ )	0.34	4.71	-1.17	5.69
	IP rights registration	0.12	1.94	1.86	12.90
	Increase rate ( $\Delta_{t+2}$ )	0.01	0.30	0.11	0.73
	Increase rate ( $\Delta_{t+3}$ )	0.01	0.32	0.10	0.76
	Tangible assets	2,160	11,600	5,277	14,900
	Increase rate ( $\Delta_{t+2}$ )	0.41	2.06	0.24	1.19
	Increase rate ( $\Delta_{t+3}$ )	0.52	2.23	0.34	1.33
	Human capital	830	2,567	1,718	2,753
	Increase rate ( $\Delta_{t+2}$ )	0.33	1.68	0.13	0.88
	Increase rate ( $\Delta_{t+3}$ )	0.41	1.73	0.19	0.95
	Marketing investment	79	913	163	937
	Increase rate ( $\Delta_{t+2}$ )	0.20	3.84	-0.01	3.52
	Increase rate ( $\Delta_{t+3}$ )	0.25	4.13	0.01	3.74

Note: Figures in parentheses denote government R&D support.

Source: *Ibid.*

In all indicators, recipients exhibited much better performance than non-recipients at the time of support.

In most performance indicators, recipients stand lower than non-recipients in terms of growth. The former even posted negative growth in operating profit and R&D investment.

#### IV. Estimation of the Causal Effects of Government Support

As firms expand in size, growth slows. Lee (2017) estimated the causal effects using the two-step unified estimation approach which integrates a non-parametric matching method and parametric regression model. The two-step approach can accurately estimate the causal effects even when only one of the two is properly specified hence is doubly robust, and can also estimate the impact of other covariates. At the matching phase,

**This study estimated the causal effects using the two-step approach which integrates the non-parametric matching method and parametric regression model.**

diverse methods were attempted, e.g. propensity score matching (PSM) and coarsened exact matching (CEM). Non-recipient firms that were most similar to recipients in terms of covariates such as R&D investment were selected by the genetic matching method, and used as the control group for causal effect estimation.

Then, an OLS analysis was conducted for the increment/increase rate of ten performance indicators after two years and the coefficients of the dummy variables of R&D support treatment were extracted (Table 3). When the impact from other covariates was controlled by combining the matching method and regression model, the negative impact observed in the simple comparison switched to a significantly positive impact in most indicators, with the exception of the value added, operating profit and sales. <Table 4> summarizes the treatment effect by the size of support. It shows that the effect on the value added, operating profit and sales is highly negative and statistically significant when the amount is over 500 million won. Debt is positive within all ranges albeit a moderate increase while equity financing exhibits a growing positive effect with statistical significance from over 200 million won. R&D investment shows the largest positive effect in the 100-500 million won range, and IP rights registration and human capital investment in over 500 million won.

**The government's R&D support contributed to SMEs' debt and equity financing, and firms expanded their investment in capabilities/assets such as intellectual properties, relational assets, tangible assets and human capital.**

In sum, the government's R&D support has contributed significantly to SMEs' debt and equity financing. And utilizing such funds, firms have expanded their investments in capabilities/assets, from intellectual properties, relational assets and tangible assets to human capital. All recipients presented an additional 5%p increase in debt financing while SMEs also exhibited an increase of over 300 million won in equity financing<sup>8)</sup> due to their advantageous position in acquiring technology guarantees and Fund of Funds. Among indicators for capabilities/assets, R&D investment and IP rights registration have consistently shown huge gains of 100%p and 30%p and marketing investment, which is deemed to be strongly complementary with intellectual property, gained over 20%p. Tangible assets and human capital posted small but significant gains in investment growth.

**Using the funding, firms invested more in capabilities/assets, but it did not lead to improving the value added, operating profit and sales growth.**

However, while the R&D support has served successfully as a catalyst for private sector investment, it has not enhanced the financial performance of the recipients. Most have failed to see improvements in their value added compared to their non-recipient counterparts, even recording significantly lower figures in sales and operating profit.<sup>9)</sup>

8) In the case of SMEs, they are influenced significantly by the government's Fund of Funds while large and middle-standing firms that rely on the public stock market were found to be influenced little by whether or not they received government support.

9) The analysis on the increments after three years reveals similar results. Two or three-year performance tracking after the completion of R&D may seem too short to evaluate the economic effects, but according to the *2016 Survey on Technology of SMEs* (2017), SMEs answered that it took an average of 10.4 months from technology development to commercialization (5.4 months for development→5.0 months for commercialization) and an additional 7.9 months to establish sales channels. Most R&D support programs for SMEs are more like short-term projects that are focused on improving competitiveness in existing products, and thus enough time to evaluate the performance of the support program. In the empirical analysis of the US' SBIR program by Edison (2010), a significant increase in sales was observed from one year after support. This study intended to check whether the additional government support could improve recipients' economic performances significantly, compared to non-recipients whose investment amount for all capabilities including R&D were similar to their counterparts. In particular, the value added embraces input indicators like R&D investment, meaning that its increase would exceed the average if operating profit does not shrink to offset the increase in inputs. Furthermore, when the evaluation targets longer period, the effects from the respective support methods tend to dissipate due to the growing impact from other noises. Oh and Kim (2010) confirmed the waning or stagnating effects in all indicators, except the debt increase rate, beyond three years after support.



**<Table 3> OLS Analysis of the Treatment Effect on the Increment of Ten Performance Indicators among All Firms and SMEs in the Matched Dataset**

(1,000 won; converted log value)

Dependent variables ( $\Delta_{t+2}$ )	All Matched Firms (29,044)			Matched SMEs (25,542)		
	Benefit	Significance	Adj. $R^2$	Benefit	Significance	Adj. $R^2$
Value added	1,252,683	0.444	0.200	38,159	0.672	0.122
Operating profit	198,364	0.883	0.207	-109,879	0.001 **	0.274
ln (sales)	-0.038	0.000 **	0.328	-0.045	0.000 **	0.345
ln (debt)	0.050	0.000 **	0.152	0.047	0.000 **	0.166
Equity financing	-2,939,290	0.254	0.653	344,495	0.008 **	0.043
ln (R&D investment)	1.039	0.000 **	0.198	1.140	0.000 **	0.220
ln (IP rights registrations)	0.301	0.000 **	0.257	0.289	0.000 **	0.324
ln (human capital)	0.024	0.022 *	0.158	0.024	0.026 *	0.129
ln (tangible asset)	0.041	0.001 **	0.124	0.048	0.000 **	0.137
ln (marketing investment)	0.207	0.000 **	0.137	0.239	0.000 **	0.158

Note: \* and \*\* denote statistical significant estimates at the 5% and 1% levels.

**<Table 4> OLS Analysis Comparison of Treatment Effects by Fund Size: Matched SMEs**

(1,000 won; converted log value)

Dependent variable ( $\Delta_{t+2}$ )	0-100 million		100-200 million won		200-500 million won		500 million one and over		Adj. $R^2$
	Estimate	Significance	Estimate	Significance	Estimate	Significance	Estimate	Significance	
Value added	168,283	0.323	72,059	0.598	180,450	0.152	-324,564	0.033 *	0.122
Operating profit	-13,125	0.835	-56,782	0.260	-35,028	0.451	-367,146	0.000 **	0.275
ln (sales)	-0.057	0.004 **	-0.024	0.135	-0.023	0.111	-0.098	0.000 **	0.346
ln (debt)	0.039	0.003 **	0.046	0.000 **	0.048	0.000 **	0.052	0.000 **	0.166
Equity financing	197,290	0.421	271,809	0.166	358,833	0.048 *	526,427	0.016 *	0.043
ln (R&D investment)	0.826	0.000 **	1.241	0.000 **	1.237	0.000 **	1.099	0.000 **	0.220
ln (IP rights registrations)	0.209	0.000 **	0.235	0.000 **	0.278	0.000 **	0.437	0.000 **	0.331
ln (human capital)	-0.061	0.003 **	0.022	0.174	0.038	0.010 *	0.068	0.000 **	0.130
ln (tangible asset)	0.071	0.004 **	0.043	0.031 *	0.047	0.010 *	0.038	0.089	0.137
ln (marketing investment)	0.184	0.016 *	0.322	0.000 **	0.146	0.009 **	0.319	0.000 **	0.158

Note: 1) \* and \*\* denote statistical significant estimates at the 5% and 1% levels.

## V. Exploring the Recipient Selection Model

A simple comparison between recipients and non-recipients revealed that, contrary to expectations, the former presented with lower growths, which an ensuing estimation of the casual effects confirmed were not due to negative treatment effects in most cases. [Figure 1] shows the population split into several subgroups (nodes) by applying



**Firms with high growth prospects were selected as recipients in a smaller proportion while those with low growth prospects were selected as recipients in a larger proportion, making the value added growth of recipients lower than the average.**

the decision tree model on the value added increment after two years. According to the figure, firms with three or more IP rights registrations a year (node 11) accounts for a mere 1% of all firms but 11% of the recipients. It is probable that they were selected based on technology competence indicators, but their value added exhibits the largest decrement of -8.7 billion won. On the other hand, small firms (node 9) with two or fewer IP rights registrations a year accounts for two-thirds of all firms but only half of the recipients despite the fact that their value added increment is large at 100 million won on average. In other words, firms with high growth prospects were the majority but a smaller proportion were selected as recipients while those with low growth prospects were the minority but a larger proportion were recipients. Consequently, the value added growth of recipients becomes lower than the average.

**Estimation of the heterogenous causal effects on the value added increments found a positive effect only in the top four deciles.**

Thus far, this study estimated the average treatment effect for the entire population. Using the causalTree method (Athey *et al.*, 2016), the population can be systematically split into numerous subgroups and then the heterogeneous causal effects can be estimated for respective subgroups.<sup>10)</sup> The subgroups are sorted in order from high to low treatment effects and the average effects were presented by decile, as can be seen in [Table 2] where deciles 1-4 are positive and deciles 5-10 are negative. The results imply that the government support had an insignificant impact on the value added growth of the entire population, not because there was no positive impact at all, but because the significant positive effect experienced by numerous recipients was offset by the negative impact experienced by the majority. The bottom decile 10 in particular shows the largest negative effect, with most firms having high value added, large equity, numerous IP rights registration, long history and high proportion of IPOs at the time of support.

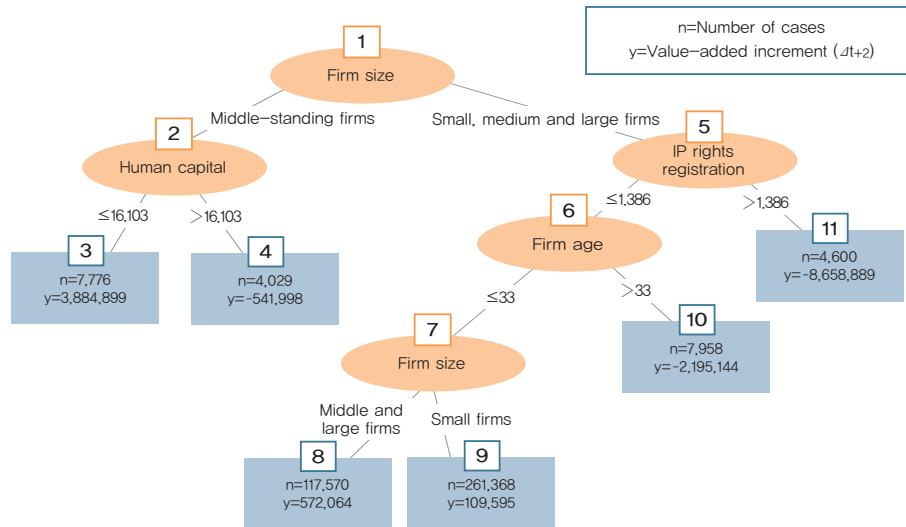
**If the support given to those with negative treatment effect was redistributed, this could double the positive effect.**

The model that estimates the heterogeneous treatment effects can predict which subgroup each firm falls into. Accordingly, if the government support assigned for recipients in the bottom six deciles (that are expected to exhibit negative effects) is redistributed to non-recipients in the top four deciles (that are expected to exhibit the opposite), the positive value added would expand two fold or more.

If the aforementioned models that predict the growth potential and heterogeneous causal effect are elaborated on further in subsequent studies, it would be possible to select recipient firms with more growth potential and better treatment effect, which will in turn help to accelerate their growth. There are sufficient records on the support for medium-sized firms to accurately predict their growth prospects and treatment effect. But, this is not the case for small firms with little experience in R&D and IP rights registration, which means that there is not enough data, as of yet, to develop a predictive model to produce accurate estimates on the policy effects. Therefore, this study suggests that experiments should be undertaken to explore the causal effects by expanding support to smaller firms.

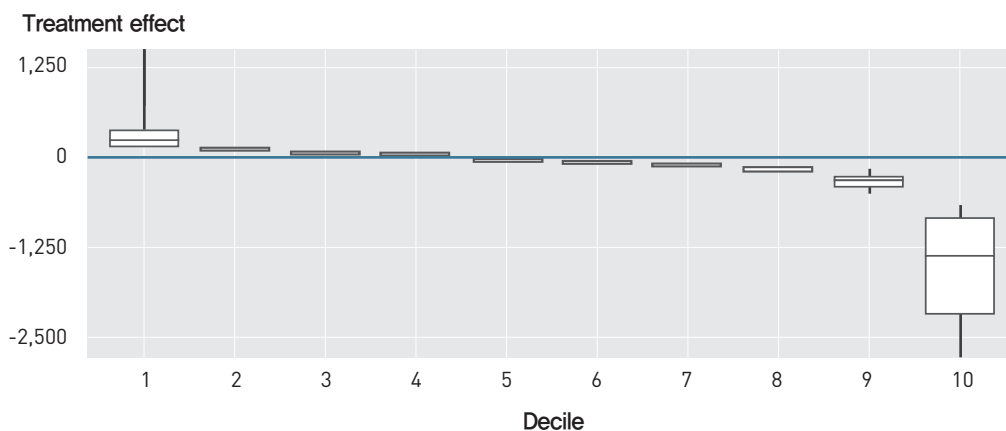
10) Random experimental data are most ideal but observed data can be utilized if the matched samples from the control group are very similar to the ones in the treatment group. The algorithm, 'propensity trees,' uses treatment variables to first determine the split of trees and then estimates the treatment effect using outcome variables in respective split nodes. It runs on the similar principle to the propensity score matching, and hence effective in estimating the heterogeneous treatment effects from the observed data.

[Figure 1] Decision Tree Model Analysis for the Estimation of the Value Added Increment after Two Years (all firms)



Number of firms	Node						Total
	3	4	8	9	10	11	
Non-recipients	7,150 (1.8%)	3,253 (0.8%)	113,580 (29.2%)	253,914 (65.3%)	7,661 (2.0%)	2,996 (0.8%)	388,554 (100%)
Recipients	626 (4.2%)	776 (5.3%)	3,990 (27.1%)	7,454 (50.5%)	294 (2.0%)	1,604 (10.9%)	14,744 (100%)
Total	7,776 (1.9%)	4,029 (1.0%)	117,570 (29.2%)	261,368 (64.8%)	7,958 (2.0%)	4,600 (1.1%)	403,301 (100%)

[Figure 2] Comparison of Treatment Effects by Decile: Value Added Increment in Matched SMEs



## VI. Suggestions for Policy Improvement

When consumer needs are ambiguous or change rapidly, the sequential completion of R&D is likely to result in a waste of time and money. Rather, the agile development method may be more effective—it enables the early release of prototypes to potential

**In keeping pace with the flexibility in corporate R&D practices, the government needs to explore an operating system in which an active exchange of feedback takes place between R&D experiments and market verification.**

customers so that firms can receive feedback and make prompt changes. In other words, shortening the ‘time to the market’ has become more imperative than reducing the costs through economies of scale (Lee and Yoo, 2017). And, such an environment offers more opportunities to SMEs and startups whose business strengths are in speed and flexibility. In the global market, unicorn companies such as Xiaomi (China), DJI (China), 23andMe (US) and L&P Cosmetics (Korea) have embraced the agile method by running quick, small experiments and quickly learning from their failures. This has helped them achieve rapid growth and outpace large enterprises who only adhere to completing R&D procedures in a perfunctory manner. In keeping pace with the rapid evolution in today’s business R&D climate, government R&D support programs need to be upgraded with more flexible operating systems in which active exchanges of feedback take place between diverse R&D experiments and market data verification processes. Based on the empirical findings, this study intends to suggest improvement measures regarding ① recipient selection, ② performance evaluation and feedback, ③ funding method, and ④ research content.

**This study suggests reforming the existing recipient selection practice which is solely based on the qualitative evaluation by technology experts, and promoting the use of the predictive model and a phased expansion of policy experiments.**

Firstly, with respect to recipient selection, a predictive model should be developed and utilized in phases while shifting away from the existing selection model, which is heavily dependent on the qualitative evaluation by technology experts. As of 2016, 22 special agencies for R&D management in Korea spent more than 2 trillion won on operating costs, which exceeds 10% of the national R&D budget.<sup>11)</sup> Government R&D support programs for the private sector have spent huge administrative costs on ex-ante, mid-term and ex-post evaluations, but recipients have exhibited slower growth than non-recipients. Howell (2017) found that even US programs saw no correlation between proposal review scores and corporate growth. It is difficult to forecast the prospects of certain firms based on their business proposals alone. The use of the predictive model reduces the management costs and enhances the economic impact. At the beginning, the model can be applied to low risk, small-scale research projects.<sup>12)</sup> More policy experiments should be attempted to provide small grants to small firms that have often been neglected in the recipient selection process. And, by delegating the selection process to an algorithm, the government will be able to become a supporter rather than a manager and only then can it focus on providing the necessary advice that can help inexperienced recipients conduct research in a more systematic way.

**Evaluations should target economic performance, not publications, IP rights and R&D amount, and a selection model should be developed to optimize the evaluation results.**

Secondly, evaluations should be focused on economic performance such as the value added and not on publications, IP rights and amount of R&D investment. Accordingly, a selection model should be developed to optimize the evaluation results. The aforementioned evidence shows that firms with three or more patents registered a year exhibit negative growth on average. The government must now discard the old belief that more patents automatically leads to higher corporate growth. The Korean government already has all the data on ministerial R&D projects integrated, which could be used to

11) The Hankyoreh, “Government R&D Budget Wasted on Management Expenses, Instead of Researches,” Oct. 7<sup>th</sup>, 2016 (in Korean).

12) Even when the predictive model is used, certain involvement by experts is necessary to determine whether to pass or fail the proposal and to provide coaching support to candidate firms, if necessary.

formulate evidence-based policy. But, not enough action has been taken thus far for policy planning, implementation and evaluation in connection to the real market and financial data. Attempts towards such policy formulation should be initiated by ministries working for industrial innovation, with the goal to drive the fourth industrial revolution.

Thirdly, because uncertainties ease as R&D and commercialization progress, firms must select the optimal funding method. For instance, at the Seed stage, small firms suffering huge financial constraints should be given a grant (no repayment required) for idea-verification research undertaken with high failure risk. And while verified ideas are developed further in full-scale, support needs to be in the form of equity investment. When facilities investment is initiated, loan support should be provided. The Korean government benchmarked the US' SBIR program. However, the programs were not systematically implemented and as a result, medium-sized firms engaging in full-scale development projects benefitted more than small firms working to prove their novel concepts. Most startups received policy financing instead of a R&D grant, but this left many in debt. The consequent losses borne by public financial corporations made it harder to provide sufficient support to firms at the growing stage (Lee *et al.*, 2015). When more grants are allocated at the initial R&D stage, the Fund of Funds and technology guarantee could provide more support to stages where the investments and loans can be utilized most effectively. In the past, when the private sector lacked the financial resources and business information, the government made the decisions on what new businesses should be selected and promoted. But, now the government must shift its attention to expanding the available choices (early research studies to experiment diverse concepts) when providing direct support via grants.

Finally, many government R&D support programs are run through project contests on designated research content, but they have been mostly inconsistent with the actual needs. As such, more free contests with bottom-up research design should be promoted. Instead of providing large financial support to a few firms, a small lump sum granted to many firms will make it easier to enhance autonomy.

**In accordance to risks associated with the respective stages of R&D and commercialization, the government needs to choose the most suitable financing methods among grants, equity investment and loan support.**

**More free contests should be offered.**

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