The Effects of the Government Research and Development Support Program on the LocalFirm's Innovative Performance*

Kyung Hee Choi(Research Professor of Daegu University)
Deok Ho Cho(Daegu University)

I. Introduction

The importance of innovation and technology development policy has considerably grown in the last 30 years(Arvanitis, Hollenstein, and Lenz, 2002).It has been proven that the firm's research and development(R&D) investment has positive effects on the firm's management performance and productivity through the introduction and development of new technologies, new processes, and new services(Kim, 2004). Many empirical evidences have emphasized the essential role played by R&D investment efforts in fostering technological change, innovation, and economic growth(Cerulli, 2010).Although the traditionalpublic good attribute of knowledge still seemsthe most known and accepted justification forpolicy intervention, other market failuressuch as capital market imperfections, barriers toentry and exit, coordination failure and so on also mightgenerate an weak provision ofprivate R&D effort(Cerulli, 2010). Therefore, it is very important that the effects of R&D invested by government are measured exactly in order to implement the governmental technology innovation policy.

The Korean government initiated the regional industrial promotion projects including the Textile Industrial PromotionProject(Daegu Milano Project) since 1999. Initially, the regional industrial promotion projects were conducted in four regions including Daegu, Busan, Gwangju, and Gyeongsangnam-do over five years. While the regional industrial promotion projects in the four regions were conducted, nine regions including Daejeon, Gyeongbuk asked expansion of the projects. The first regional industrial promotion projects in the nine regions including Gyeongbuk were conducted since 2002, and the second regional industrial promotion projects in the nine regions were conducted since 2008, and the second projects were finished in 2012. One of the characteristics of the regional industrial promotion projects in the nine regions is that the government supported the R&D expenditure as well as infra-building (KDI, 2004). The second regional industrial promotion projects in nine regions including the Gyeongbuk area were finished in 2012, and the Gyeongbuktechnopark as a innovation hub surveyed the performance of the projects over five years. The survey was done on the regional industrial support programs which include the regional strategic industrial promotion programs and the specialized regional industrial promotion programs implemented in Gyeongbuk region from 2008 to 2012.

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** Corresponding Author

These projects include technology development, technology support, marketing support, human resources training, building of innovation hub, and the planning agency of the regional strategic industry, and this study is focusing on the program of technology development and technology support considered as the government R&D support. This study is trying to investigate the effect of government's R&D support policies. Especially, this study is aimed to analyze the effect of R&D support policies on innovative performance of the Gyeongbuk area.

However, it is difficult to examine the net effects of these R&D projects because the project effects are correlated with each other. The traditional method to estimate the impact of publicfunding on private R&D spending eventually has focused on the measure the effect of subsidy on private R&D, controllingfor other variables in an OLS regression (Clausen, 2009).This method basically assumes that R&D subsidies areallocated to firms randomly and independently. And then simple comparison between the performances of the group treated and the group not treated results in the bias in the estimation of the effects of the treatment because of the selection bias. The important issue in investigating the performance of the government R&D support programs is the choice of valid method which reduces the selection bias. Especially new technology developments, their diffusion and adoption, organizational change and innovative behavior have raised new methodological challenges for the evaluation of these policies (Arvanitis, Hollenstein and Lenz, 2002).Rosenbaum and Rubin(1983) propose the propensity score matching as a method of estimating the effect of the treatment. The matching method deals with the selection bias by controlling the covariates affecting the participation in the government program and its effects.

This study basically focuses on the analysis of the net effect of the government R&D support program on the local firms' technology development and its performance. And then it examines whether and how much the above program raises the effects of local firms' technology development and its performance. It tries to investigate the net effect of government's R&D support policies. Especially, it focuses on analyzing the effect of R&D support policies on the innovative performance of local firms in the Gyeongbuk area where these programs are implemented for the first time in Korea. More specifically it evaluates the performance of the government R&D support programs, using the propensity score matching. This study finally suggests the R&D support policy alternatives and gives some lessons to the other programs and areas.

II. Government R&D support and the firms' innovative performance

1. Government R&D support for the regional Small and Medium Size Firm Effects

Many studies figure out the R&D efforts at the firm level, and argue that it improves performances and competitive stances (Conceicao, Hamill and Pinheiro, 2001). Cerulli(2010) investigates the rationale for R&D subsidization. The neoclassical theory based on a positive externality argument suggests that, because of the 'public good' characteristics of R&D activities, the level of private R&D expenditure would be systematically lower than the socially optimal level. It argues that government intervention through subsidisation can reduce the extent of this market failure.Cerulli(2010) suggests additional reasons for subsidization associated with the market failure such as: "(i) imperfect capital markets; (ii) lack of markets for high-risk investments; (iii) overly high barriers to entry and exit; (iv) excessive market power or, conversely, excessive fragmentation of market power; (v) lack of technological infrastructures and bridging institutions; and (vi) coordination failure of profitable R&D joint ventures, producing duplications in R&D efforts and other wastes of resources(p.423-424)."

The governmentinterventions in industries' R&D and innovations are a general phenomenon, and especially governments in developing countries play a role of entrepreneur more than those in advanced countries(Choi and Kim 2013). They argue that government's financial support influences corporate growth in Singapore. They also note that small businesses' main benefits from the government are administrative and operational aids.

However, government programs to mitigate market failures may generate incentives that lead the private sector not to implement many of the programs' intended benefits and such incentives may be especially prevalent in today's government-industry technology programs.Wallsten(2000) explores the incentives affecting the design and implementation of government-industry R&D programs.First, program proponents are unlikely to implement a monitoring system that identifies projects that would have been pursued without government subsidies.Second, politicians are unlikely to support a program that refuses to support commercially attractive proposals. He (2000) asks whether government-industry commercial R&D grants increase private R&D. He also estimates a multi-equation model to test the hypotheses and concludes that firms with more employees and that appear to do more research win more SBIR grants, but that the grants do not affect employment.Clausen(2009) also analyzes whether and how 'research' and 'development' subsidies influence private R&D activity. The analysis was done in a two stage least squares regression. His empirical results show that 'research' subsidies stimulate R&D spending within firms while 'development' subsidies substitute such spending.

The firmsalways have an incentive to apply for the public R&D support, even if they could perform the R&D projects using their own private finances. If the public support is granted, then the firm might simply substitute public investment for private one. And then this possible crowding-out effect between public grants and private investments must be taken into account when public authorities decide on the level of their engagement in R&D support programs(Almus and Czarnitzki, 2003).

2. Firm's use of government R&D support and the firm performance

There are some empirical studies about the effects of government R&D supporton the private firms. Thesestudies mainly focus on the evaluation of the performance of the government R&D supportbut deal with different variables and use diverse methods.More specifically Suh and Lee(2007) analyze the determinants of firm's innovative activities and specify the role of national R&D program on SME'sinnovative activities. Their research results show that the national R&D programfacilitates the enhanced performance of technology management of the firms. Shin and Choi(2008) suggest that R&D intensity was influential determinants to SMEs' innovation. And they also suggest that the interaction between R&D intensity and fund support, and the interaction between R&D intensity and labor support had a positive and significant effect on SMEs' innovation. These studies investigate the relationship between the firm's R&D and firm's innovativeness. The former uses the certification of technology of innovative SMEs as a dependent variablewhich is the firm's degree of the technology management. And, this study uses the firm age, size, sales, the R&D expenditure, the R&D staffs, the ratio of the export to sales, the organization of R&D, technology strategy, the R&D management, the management of the knowledge property and so on as the independent variables. Shin and Choi(2008) measure the firm's R&D as the ratio of the R&D staffs to the total employment, and the firm's innovativeness as the number of the knowledge property certified in recent three years. And, they measures the R&D support policies as the subjective evaluation of the government support. Lee(2005) investigates the difference between the group treated and not treated on the variables of the strategies of technology innovation such as R&D expenditure, R&D intensity, and R&D staffs. He suggests that the relative level of innovation activities was not different between the group supported and the group not supported.

Lee and Lee(2008) investigate the effects and success factors of the Korean government's Design Development Assistance Program(DDAP) by implementing the regression analysis including the design performance and the economic performance as the dependent variables and the government support subsidy as an independent variable. They conclude that support for small businesses has only temporary effects, and the effects do not improve theeconomic performance.Choi and Kim(2013) suggest that government certification and venture capital investment facilitated the corporate growth. They used the survival analysis including the time spent to become a IPO(initial public offering) as the dependent variable, and the government certification, the venture capital investment as the independent variables. Yoon and Koh(2011) analyzes the effect of government-sponsored R&D on firm's employment and management performance, using the panel data of manufacturing firms in the area of Busan, Ulsan and Gyungnam. They conclude that government-sponsored R&D in the areas has positive effects on the participating firms' employment and R&D for several years after completing R&D projects.However, most researches focused on the nation-wide analysis, and did not suggest the specific program effect of local level. Their methods also used the ordinary regression but this method cannot solve the sample selection bias of survey data.

III. Research Method: Propensity Score Matching

1. Observational studies and the estimation of the Average Treatment Effect on the Treated(ATT)

This study is aimed to estimate the effects of public R&D support on local firms' innovative performance. This study is interested in the evaluation of the performance of the government R&D policy as a whole focusing on the firms located in Gyeongbuk region.In order to estimate the effects of government R&D support program in this area, at first this study should distinguish the treated group with the untreated group and note its outcome effects with and without programs.

Rubin (1977) defines the effects of treatments and suggests the assumptions for estimating the effects of treatments. First assumption is that X is unaffected by the treatments. Second assumption is no interference between units. He denotes the average effects of treatments as equation (1). The average effect of Treatment 1 vs. Treatment 2 on Y in P, $\tau = \mu_1 - \mu_2$, is $\mu_1(x) - \mu_2(x)$ averaged over the distribution of X in P. This relationship is used to estimate τ in non-randomized studies.

$$\tau = \underset{x \in P}{ave}[\mu_1(x) - \mu_2(x)] \qquad (1)$$

Where μ_1 is the resulting average value of Y for all units in P, and $\mu_1(x)$is the resulting average value of Y for all those units in P with score x on variable X supposing that all units in P were exposed to treatment 1. $\mu_2$is the resulting average value of Y for all units in P, and $\mu_2(x)$ is the resulting average value of Y for all those units in P with score x on variable X.

Cerulli(2012) emphasizes that nonrandom assignment of public funds embeds R&D policies in a non-experimental setting. It means that the treatment variable and the outcome variable are stochastically dependent and that we cannot use classical inference approach like regression analysis because of sample selection bias.Sources of selection bias are, non overlapping supports of X in the treated and comparison group(i.e., the presence of units in one group that cannot find suitablecomparison in the other);unbalance in observed confounders between the groups of treated andcontrol units; unbalance in unobserved confounders between the groups of treatedand control units (Grilli and Rampichini, 2011).

2. Propensity score matching

Rubin (1973) suggests that the matching methods can remove the bias in observational or nonrandomized studies. Matched sampling is a method of data collection designed to reduce bias and variability due to specific matchingvariables(Rubin, 1976). Matching is a method of sampling from a large reservoir of potential controls to produce a control group of modest size in which the distribution of covariates is similar to the distribution in the treated group (Rosenbaum and Rubin, 1983). Hausman (2001) states that matching approaches lead to more robust estimates of the treatment effect compared to other methods(Almus and Czarnitzki, 2003). Matching is a non-parametric technique, so it avoids potential misspecification and it allows for arbitrary heterogeneity in causal effects(Grilli and Rampichini, 2011).

Rubin (1974) suggests that nonrandomized studies can be useful in estimating causal treatment effects. He emphasizes that very well-controlled nonrandomized study conducted on a representative sample of trials is good. Rubin (1977) suggests that three steps are essential in order to estimate causal effects of treatments in those studies which are not classical randomized designs. (a) recording the variable X used to make assignment decisions, (b) estimating the conditional expectations of Y given X in each treatment group,and(c) averaging the difference between the estimated conditional expectations over the estimated distribution of X in the relevant population.

In randomized experiments, the results in the two treatment groups may often be directly compared because their units are likely to be similar, whereas in nonrandomized experiments, such direct comparisons may be misleading because the units exposed to one treatment generally differ systematically from the units exposed to the other treatment. Balancing scores can be used to group treated and control units so that direct comparisons are more meaningful(Rosenbaum and Rubin, 1983).

Rosenbaum and Rubin (1983) suggest the use of balancing scores. A balancing score, b(x), is a function of the observed covariates x such that the conditional distribution of x given b(x) is the same for treated and control units (Rosenbaum and Rubin, 1983). If treatment assignment is strongly ignorable given x, the difference between treatment and control means at each value of a balancing score is an unbiased estimate of the treatment effect at that value. The propensity score is a balancing score and the propensity towards exposure to treatment given the observed covariates X(Rosenbaum and Rubin, 1983). If we take individuals with the same propensity score, and divide them into two groups-those who were and weren't treated-the groups will be approximately balanced on the variables predicting the propensity score (Chen, 2008).

3. Assumption: strongly ignorable treatment assignment

Rosenbaum and Rubin (1983) suggests the assumption of strong ignorability for the estimation of the treatment effect. They express the two assumption of strong ignorability as follows.

$$(r_{1,} r_0) \perp z|v, \quad 0 < pr(z = 1|v) < 1 \qquad (2)$$

Where r_1 is a response that would have resulted from treatment 1 and r_0 is a response from treatment 0.zis the treatment and v is the covariate. First, Treatment assignment z and response (r_0, r_0) are conditionally independent. Second, every unit in the population has a chance of receiving each treatment.

For the analysis of observational data, we try to structure it so that we canconceptualize the data as having arisen from an underlying regularassignment mechanism.Regular designs are likecompletely randomized experiments exceptthat the probabilities of treatment assignment are allowed to dependon covariates, and so can vary from unit to unit.Regular designs have two features: 1) they are unconfounded, 2) the individual assignment possibilities as a function of the covariatesare strictly between zero and one (Grilli and Rampichini 2011). In other words, the satisfaction of selection of observables and common support enables us to use the (observed) The additional common support condition focuses on comparison ofcomparable subjects (Grilli and Rampichini, 2011).

In a nonrandomized experiment, the propensity score function is almost always unknown so that there is not one accepted, however, the propensity score may be estimated from observed data, perhaps using a model such as a logit model (Rosenbaum and Rubin, 1983).It is not possible to fully measure characteristics of firms that might receive greater attention by government (Sakakibara, 2002). In general, the choice of covariates to insert in the propensity score modelshould be based ontheory and previous empirical findings. Only variables that influence simultaneously the treatment status and the outcomevariable should be included. Given that unconfoudedness requires the outcome variables to be independent oftreatment conditional on the propensity score, we must choose a set of X thatcredibly satisfy this condition.Only variables that are unaffected by treatment should be included in the model.On the other hand, a variable should only be excluded from analysis ifthere is consensus that the variable is either unrelated to the outcomeor not a proper covariate.If there are doubts about these two points,Rubin and Thomas (1996) recommend to include the relevantvariables in the propensity score estimation (Grilli and Rampichini, 2011). In calculating the propensity score, we can use replacements, or not eliminating participants from the matching pool once matched. Matching with replacement keeps bias low at the cost of larger variance. Matching without replacement keeps variance low at the cost of potential bias (Grilli and Rampichini, 2011). We should decide which matching algorithm to use among Nearest Neighbor, Caliper & Radius, Stratification and interval and Kernal&Loca Linear (Chen and Zeiser, 2008). We can consider only the observations whose propensity score belongs to the interaction of the propensity score of treated and control (Grilli and Rampichini, 2011).

4. Balance checking

Although it is not possible to test the validity of conditional independence assumption (CIA) formally (Almus and Czarnitzki, 2003), by including the variables that influence simultaneously the treatment status and the outcomevariable, we can ensure the assumption of the conditional independence

To check the matching quality, we need to check balance property and we can use the stata command pstest. After checking balancing, we can trust the ATT estimation (Grilli and Rampichini, 2011). We can check overlap by routines for common support graphing, and we can use the stata command psgraph.

We can interpret that R&D subsidy programs have on average a positive impact on the firm performance if the causal effect (AAT) is significantly greater than zero.The programs do not generate positive effects ifthe causal effect (AAT) is statistically insignificant.Finally, subsidized firms perform worse than firms without subsidiesif the causal effect is significantly smaller than zero (Almus and Czarnitzki, 2003).

The test on the effect is usually carried out by means of a simple t–statistic.In this case, however, the ordinary t–value is biased upwards because it doesnot take into account that the mean of the outcome variable of the controlgroup is not a result of a random sampling but an estimation: it is based onthe estimated propensity scores and the non-parametric matching procedure.Thus, the usual t–statistic may be misleading for making inferences. Toremove the bias of the t–statistic, the method of bootstrapping is applied,i.e. we simulate the distribution of the mean outcome of the control groupby repeated (Almus and Czarnitzki, 2003).

IV. DataDescriptionand Analysis Results

1. Data Description

This study uses the survey on the performance of the Regional Industry Support Program conducted by DGB Management Consulting Center on behalf of the Gyeongbuktechnopark in 2012. The Regional Industry Support Programs were initiated in 1999 and include the technology development, technology support project, marketing support project, human resource training project, knowledge services. The Regional Industry Support Programs of Gyeongbukarea were initiated since 2002. The period of the first Regional Industry Support Programs was from 2002 to 2007. The period of the second Regional Industry Support Programs was from 2008 to 2012. Gyeongbuktechnopark as local innovation hub tried to evaluate the performance of the Regional Industry Support Programs to design the next stage Regional Industry Support Programs.

The survey was conducted on the performance of 545 firms which were participating in the programs. We used 508 small and medium sized firm data because this study is focusing on the SMEs. 82 firms were participating in the technology development project, and 89 firms were participating in technology support project. 15 firms were participating in technology development and technology support project simultaneously. This study is considering the 156 firms which were participating in technology development and technology support project as firms participating in government R&D support. <Table 1> shows the characteristics of the firms surveyed.

<Table 1> Characteristics of the Firms(1)

variables		Frequency/mean	
firms' R&D institute	holding	211	41.87
	not holding	293	58.13
	sum	504	100
Corporate age (years)		10.37	
Firms' size	small sized	391	76.97

	medium sized	117	23.03
	sum	508	100
industry	Electronics/Information appliances	45	8.86
	New Material/ Component Industry	290	57.09
	Biological Industry/ Herbal Medicine Industry	151	29.72
	etc.	22	4.33
	sum	508	100

The firms holding the research facilities are 211(41.87%). The average age of the firms is 10.37 years old. The number of small sized firms with less than 50 employees is 391(76.97%) and medium sized firms with more than 50 employees and less than 300 employees is 117(24.03%). Firms in the survey are from diverse business sectors, Electronics/Information appliances, New Material/Component Industry, Biological Industry/Herbal Medicine Industry, and etc. The number of the firms in the sector of Electronics/Information appliances is 45, in the sector of New Material/Component Industry is 290, in the sector of Biological Industry/Herbal Medicine Industry is 151, and in etc. is 22.

The surveyed firms were requested to respond about sales, employees, R&D personnel, production personnel, etc. for 2008, 2009, 2010, 2011, and 2012. The average sales, employee, R&D personnel, production personnel, proportion of R&D personnel, tangible assets, profit, net profit are shown on <Table 2>

<Table 2>Characteristics of the Firms(2)

		2008	2009	2010	2011
Sales(million won)	num	366	420	445	426
	mean	9651.32	8905.04	10488.18	12413.77
Employee(persons)	num	261	372	366	353
	mean	44.39	41.02	37.57	42.32
R&D personnel(persons)	num	172	215	238	235
	mean	4.46	4.28	4.66	5.45
Production personnel(persons)	num	246	344	337	328
	mean	27.33	24.87	23.43	26.09
Proportion of R&D personnel	num	169	213	235	229
	mean	0.22	0.22	0.26	0.25
Tangible assets(million won)	num	508	428	443	414
	mean	2833.65	3739.16	3758.02	4277.94
Profit(million won)	num	508	432	448	429
	mean	433.47	2054.09	716.07	908.55

Net profit(million won)	num	508	432	450	424
	mean	190.59	687.27	741.90	839.73

This study includes the variables indicating the firms' performance- the number of the new employees, the sales of the new products, the number of the commercialization of the developed technology, the exports, the number of articles, the number of registered industrial property rights, the number of domestic patent applications piled, the number of the registered domestic patents, the number of international patent application piled, the number of the registered international patents, the number of the prototype development, the number of new product development, the number of product process improvement, the domestic sales based on the commercialization of the developed technology, the export sales based on the commercialization of the developed technology.

<Table 3>Characteristics of the Firms(3)

		2008	2009	2010	2011
New employees(persons)	num	490	496	499	497
	mean	4.09	7.17	4.97	4.96
Sales of new products (million won)	num	481	482	484	486
	mean	28.99	38.52	86.98	91.78
Commercialization(number)	num	479	481	484	484
	mean	0.10	0.11	0.21	0.32
Export(thousand dollar)	num	483	486	487	486
	mean	380.62	309.59	491.63	859.12
Domestic (sci) article(number)	num	1	2	2	3
	mean	1	1	1.5	1.33
Utility model(number)	num	10	7	4	5
	mean	1.4	1.29	2	1.4
S/W(number)	num	1	1	1	1
	mean	1	2	1	1
Design(number)	num	5	2	1	4
	mean	2	1.5	2.75	7
Etc(standard acquisition) (number)	num	4	8	9	3
	mean	1.75	1.13	1.11	1.33
Domestic patent application piled (number)	num	21	36	44	53
	mean	1.81	2.08	2.02	2.25
Registered domestic patents (number)	num	31	27	35	47
	mean	1.77	1.93	1.74	2.04
International patent application	num	3	5	9	6