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Effects of Government Research and Development Support Policies on Local Firms' Innovative Performance

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Effects of Government Research and Development Support Policies on Local Firms' Innovative Performance

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Abstract

The importance of innovation and technology development policy has grown considerably recently. To provide a sound basis for policy guidance in the field of R&D support policy, it is important to evaluate the effect of the R&D support policies. This study uses the propensity score matching to analyze the net effect of government R&D support policies on local firms' innovative performance. We found that the R&D support policies had positive effects on variables such as commercialization of the developed technology, articles, domestic patent applications, registered domestic patents, and new product development, but were not statistically significant in relation to variables such as registered industrial property rights, international patent applications, prototype development, product process improvement, etc. Therefore, we suggest that the R&D support policies implemented in the Gyeongbuk region have significantly contributed to the improvement of local firms' innovative performance in some aspects.

Key Words: innovation and technology, Propensity Score Matching, research and development

I. Introduction

The importance of innovation and technology development policy has grown considerably in the last 30 years (Arvanitis, Hollenstein, and Lenz, 2002). It has been proven that a firm's research and development (R&D) investment has positive effects on its management performance and productivity through the introduction and development of new technologies, new processes, and new services (Kim, 2004). Many empirical studies have emphasized the essential role played by R&D investment efforts in fostering technological change, innovation, and economic growth (Cerulli, 2010). In order to provide a sound basis for policy guidance in the field of R&D support policy, it is important to understand the factors explaining the rationale for R&D subsidization, the functioning of firm R&D strategy, and the techniques to measure incentive effectiveness (Cerulli 2010).

The Korean government has supported the development and transfer of technology through the R&D policies since the early 1980's (Lee and Kim, 2007). It has initiated the regional industrial promotion projects including the Textile Industrial Promotion Project (Daegu Milano Project) since 1999. The regional industrial support

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policies implemented in Gyeongbuk region from 2008 to 2012 include technology development, technology support, marketing support, human resources training, building of innovation hub, and the planning agency of the regional strategic industry. This study focuses on the programs of technology development and technology support considered as the government R&D support policies. There are few existing studies in relation with the regional industrial support policies of Gyeongbuk region. Kim (2010) explores barriers to collaboration among policy actors in the policy delivery system. However, it is very important to accurately measure the effects of past R&D investment by the government to direct future technology innovation policy.

The traditional method to estimate the impact of public funding on private R&D spending has focused on measuring the effect of subsidies on private R&D while controlling for other variables in an OLS regression (Clausen, 2009). This method assumes that R&D subsidies are allocated to firms randomly and independently. However, there is no guarantee of randomness because firms often self select or are picked by policy makers, which leaves results subject to selection bias (Clausen, 2009). Selecting a valid method to investigate the performance of government R&D support policies with the reduced selection bias remains an important issue (Arvanitis, Hollenstein and Lenz, 2002).

We look specifically at the effect of R&D support policies on the innovative performance of local firms in the Gyeongbuk region, where these policies are being implemented for the first time in the Republic of Korea. Despite the rules requiring the evaluation of the regional industrial support policies and the needs of performance evaluation, the quantitative evaluation of the performance of the regional industrial policies is not active. Nonrandom assignment of public funds embeds R&D policies in a non-experimental setting (Cerulli, 2012), and there are some problems of self-selection and maturation effect in implementing the non-experimental study. This study uses the propensity score matching to deal with such problems and to estimate the net effects of R&D subsidies. This study uses the STATA command `psmatch2` to implement the propensity score matching. Finally this study suggests some policy implications.

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

1. Government R&D support for the regional Small and Medium-sized Enterprises (SMEs)

Many studies look at R&D efforts at the firm level, and argue that such efforts improve performance and competitiveness (Conceicao, Hamill and Pinheiro, 2001). Cerulli (2010) investigates the rationale for R&D subsidization. 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. If there is technological potential but the level of commercialization is weak, the government may selectively intervene to resolve the initial lack of funds (Park, 2009). Government intervention in industries' R&D and innovations is a general phenomenon, especially in developing countries where they

play the role of entrepreneur more than in advanced countries (Choi and Kim, 2013). Choi and Kim also note that small businesses' main benefits from the government are administrative and operational aids.

However, government policies to mitigate market failures may generate incentives that lead the private sector not to implement many of the policies' intended benefits. Such incentives may be especially prevalent in today's government-industry technology policies. Wallsten (2000) explores the incentives affecting the design and implementation of government-industry R&D policies. First, he suggests policy proponents are unlikely to implement a monitoring system that identifies projects that would have been pursued without government subsidies. Second, he claims politicians are unlikely to support a policy that refuses to support commercially attractive proposals. Government R&D support policies can induce the crowding out effect between public grants and private R&D investment (Almus and Czarnitzki, 2003). The argument on the standard basic neoclassical model has been criticized by the evolutionary perspective and the New Industrial Organization theory that suggest that the firm R&D could be excessive (Cerulli, 2010). Clausen (2009) 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 demonstrate that research subsidies stimulate R&D spending within firms while development subsidies substitute such spending.

2. A firm's use of government R&D support and its impact on the firm's innovative performance

Empirical studies have been carried out on the effects of government R&D support on private firms. These studies mainly focus on evaluation of the performance of the government R&D support, but also deal with different variables and use diverse methods. Suh and Lee (2007) analyze the determinants of firm's innovative activities and specify the role of national R&D policy on small and medium-sized enterprises' (SMEs') innovative activities. They used logistic regression and included the national R&D policy as the moderating variable. Their research result shows that the national R&D policy facilitates the enhanced performance of technology management of the firms. Shin and Choi (2008) suggest that R&D intensity was an influential determinant of SMEs' innovation. 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. Shin and Choi (2008) measure firm's R&D as the ratio of its R&D staff to a firm's total employment. They measure a firm's innovativeness as the number of intellectual properties certified in the last three years. Lee (2005) investigates the difference between the subsidized and unsubsidized groups on variables related to strategies of technology innovation such as R&D expenditure, R&D intensity, and R&D staff.

Lee and Lee (2008) investigate the effects and success factors of the Korean government's Design Development Assistance Policy (DDAP), and conclude that support for small businesses has only temporary effects and the effects do not improve economic performance. Choi and Kim (2013) suggest that government

certification and venture capital investment facilitate corporate growth. Yoon and Koh (2011) analyze the effect of government-sponsored R&D on a firm's employment and management performance using the panel data of manufacturing firms in the Busan, Ulsan and Gyungnam regions. Kim and Kim (2012) investigate the effects of public R&D subsidies on private R&D using propensity score matching. They conclude that, on average, public R&D funding complements private R&D investment. Cho (2009) analyze the effects of the government R&D subsidies on the firm innovation. He considers the fact that the firm innovation includes diverse activities and performances from the participation in the innovative activities to the final economic performance, and focuses on the whole procedure of firms' innovative activities such as participating in the innovative activities, deciding investment level, achieving technological innovation, and reaping economic outcomes of innovation.

III. Research Method: Propensity Score Matching (PSM)

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 policies in this area, this study uses the propensity score matching suggested by Rosenbaum and Rubin (1983).

The intuitive notion of causal effect is the difference between the response measured on a unit that is exposed to cause or treatment t and the response that would have been measured on the same unit if it had been exposed to treatment c (Holland and Rubin, 1988). When randomization is used to assign units to exposure to the treatments, the variable of causal indicator is made statistically independent of all other variables defined on a population of units.¹ Rosenbaum and Rubin (1983) define a special condition that generalizes randomization. They suggest the assumption of strong ignorability for the estimation of the treatment effect. They express the two assumptions of strong ignorability as follows.

$$(r_1, r_0) \perp z|v, \quad 0 < pr(z = 1|v) < 1 \quad (1)$$

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

Rubin (1977) denotes the average effects of treatments (ATT) as equation (2). 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 the population P . This relationship is used to estimate τ in non-randomized studies.

$$\tau = \mathop{ave}_{x \in P} [\mu_1(x) - \mu_2(x)] \quad (2)$$

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. μ_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.

Rosenbaum and Rubin (1983) suggest the use of the propensity score to group treated and control units so that direct comparisons are more meaningful. 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). In a nonrandomized experiment, the propensity score function is almost 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). In general, the choice of covariates to insert in the propensity score model should be based on theory and previous empirical findings (Grilli and Rampichini, 2011).

This study should decide which matching algorithm to use among Nearest Neighbor, Caliper & Radius, Stratification and interval, and Kernel & Local Linear (Chen and Zeiser, 2008). Each method has its own merits and weaknesses without the priority to other methods in the statistical aspects (You and Kang, 2010). This study chooses Kernel matching method.² In the Kernel-based matching, a treated firm is matched to all non-treated firms in the control group, but the controls are weighted according to the Mahalanobis distance between the treated firm and each non-treated firm (Aerts and Schmidt, 2008). This study considers only the observations whose propensity score belongs to the interaction of the propensity score of treated and control.

Although it is not possible to test the validity of Conditional Independence Assumption (CIA) formally, we can ensure the assumption of the conditional independence by including the variables that influence simultaneously the treatment status and the outcome variable (Almus and Czarnitzki, 2003). 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 a positive impact on the firm performance if the causal effect (AAT) is significantly greater than zero. The programs do not generate positive effects if the causal effect (AAT) is statistically insignificant. Finally, subsidized firms perform worse than firms without subsidies if 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. However, the ordinary t -value is biased because it does not take into account that the mean of the outcome variable of the control group is not a result of a random sampling but an estimation of propensity scores. To remove the bias of the t -statistic, the method of bootstrapping can be applied (Almus and Czarnitzki, 2003).

IV. Data Description and Analysis Results

1. Data Description

This study uses survey data on the performance of the Regional Industrial Support Policies conducted by DGB Management Consulting Center on behalf of the Gyeongbuk Technopark in 2012. The survey was conducted on the performance of 544 firms which participated in the Regional Industrial Support Policies from 2008 to 2012. We used 427 observations of small and medium-sized firms established before 2008. The Observations of the firms established after 2009 were not used by this study because the outcome variables are the sum values for the outcomes from 2008 to 2012. 127 firms participated in technology development or support projects. Thirteen firms were involved in technology development and technology support simultaneously. The remaining 300 firms are considered as the potential control group. <Table 1> shows the characteristics of the firms surveyed.

<Table 1> Characteristics of the Firms and Measurement

variables		Frequency (percent)	
R&D support	Supported	127	29.74
	Not supported	300	70.26
	sum	427	100
Firms' R&D institute (2008)	Holding	190	44.50
	Not holding	237	55.50
	sum	427	100
Corporate age in 2012 (years)			11.87
Firms' size	Small-sized	317	74.24
	Medium-sized	110	25.76
	sum	427	100
Industry	Electronics/Information appliances	34	7.96
	New Material/Component Industry	254	59.48
	Biological Industry/Herbal Medicine Industry	120	28.10
	Other Industries	19	4.45
	sum	427	100

This study estimated the logit model to gauge a firm's probability to receive R&D support given observable covariates. It then checked the balancing property and estimated the average treatment effect.

This study selects several covariates considering the previous studies. This study includes the followings as covariates: dummy variable indicating whether firms have R&D institutes in 2008,³ age of the firm in 2008,⁴ size of the firm,⁵ industry dummies,⁶ proportion of tangible assets relative to total employment in 2008,⁷ proportion of sales relative to total employment in 2008,⁸ proportion of profit relative to sales in 2008,⁹

proportion of R&D employment relative to total employment in 2008,¹⁰ and net profit in 2008.¹¹ As the subsidy dummy covers a 5-year period, this study uses the values of the covariates measured at the beginning of the project period in order to avoid endogeneity problems.¹²

This study considers the argument that the firm innovation includes diverse activities and performances, and includes several potential outcome variables indicating diverse aspects of innovative performance. The potential outcome variables are as follows: new employees, sales of new products, exports, commercialization of the developed technology, articles,¹³ registered industrial property rights,¹⁴ domestic patent applications piled, registered domestic patents, international patent applications piled, registered international patents, prototype development, new product development, product process improvement, domestic sales through commercialization, and export sales through commercialization. The data used shows five year values for the outcome variables. We generated the sum values of five years for each outcome variables by firms, and used the sum values as the outcome variables in implementing the psmatch2. Yoon and Koh (2011) consider the yearly outcomes such as R&D expenditure, sales and profits, number of new employees as the outcome variables. Their outcome variables such as R&D expenditure, sales and profits are measured by the amount of money. In our study, many outcome variables are measured by the number of the output such as commercialization, so the number is not large. So, this study uses the sum values for the outcomes to make some variations among the observations. This study used the Kernel matching to minimize the bias and imposed a common support to improve the quality of the matches.

2. Analysis Results

The two-sided t-test statistically indicates significant differences between the subsidized firms and the potential control group of non-subsidized firms in relation with firm age, the dummy variables of the new material and component industry, and other industries as shown in <Table 2>.

<Table 2> Descriptive statistics of the sample (t-test)

Variables	Subsidized companies		Potential control group of non-subsidized companies		t-stat	p-values (two-sided)
	Mean	Standard Error	Mean	Standard Error		
Firms' R&D institute in 2008	0.49	0.04	0.43	0.03	-1.17	0.24
Corporate age in 2008 (years)	6.64	0.56	8.39	0.42	2.37	0.02
Firms' size	0.24	0.04	0.27	0.03	0.66	0.51
Electronics/Information appliances	0.07	0.02	0.08	0.02	0.43	0.66
New Material/	0.67	0.04	0.56	0.03	-2.04	0.04

Component Industry						
Biological Industry/ Herbal Medicine Industry	0.25	0.04	0.29	0.03	0.87	0.39
Other Industries	0.01	0.01	0.06	0.01	2.40	0.02
Proportion of tangible assets relative to total employment in 2008	59.15	7.67	102.99	26.44	1.09	0.28
Proportion of sales relative to total employment in 2008	196.60	18.36	237.85	28.72	0.94	0.35
Proportion of profit relative to sales in 2008	-0.24	0.14	-0.05	0.07	1.33	0.18
Proportion of R&D employment relative to total employment in 2008	0.26	0.04	0.21	0.02	-1.28	0.20
Net profit in 2008	135.35	68.48	264.41	269.47	0.31	0.76

This study estimated the logit model including the dummy variable indicating whether the firms received the government R&D support as a dependent variable and analyzed the firm characteristics influencing its participation in the government R&D support policy. The firms in the industries of Electronics/Information appliances and New Material/Component are more likely to participate in the government R&D support policies. And, the proportion of R&D employment relative to total employment will affect the probability that firms participate in the R&D support policies. Effects for the logit model can be interpreted in terms of a change in the odds a firm will participate like <Table 3>. The odds ratios of the dummy variables of the Electronics/Information appliances and New Material/Component industry are very large.¹⁵ The odds ratio of the proportion of R&D employment relative to total employment is 6.028. For a unit change in the proportion of R&D employment relative to total employment, the odds of participating in the government R&D support are expected to change by a factor of 6.028, holding all other variables constant.

<Table 3> Result of logit analysis

Variables	Coef.	Std. Err.	z	P>z	odds ratio
ins2008	0.180	0.415	0.43	0.664	1.197
age2008	-0.020	0.025	-0.78	0.434	0.981
size_dum	0.681	0.436	1.56	0.118	1.976
Elec	24.549***	1.163	21.11	0	4.59E+10
Newmaterial	25.903***	0.443	58.51	0	1.78E+11
bio	25.360	.	.	.	1.03E+11
ma_em2008	-0.001	0.002	-0.64	0.524	0.999
sal_em2008	-0.001	0.001	-1.1	0.272	0.999
profit_sal2008	-0.418	0.276	-1.51	0.13	0.659

rd_emp2008	1.796*	1.005	1.79	0.074	6.028
net2008	0.000	0.000	0.69	0.489	1.000
_cons	-26.593	0.554	-47.98	0.000	
Number of obs			155		
LR chi2			21.65		
Prob>chi2			0.0272		
Pseudo R2			0.1080		

Significance level: 0.01(***), 0.05(**), 0.1(*)

Given the firm characteristics that simultaneously influence participation in the R&D support policies and the potential outcome, we can calculate the propensity score. We can match the firms which are similar in relation to propensity score, and compare the average of the response variables of the supported group and unsupported group. We should also investigate the balancing property. Considering the p-value of the T-test, we cannot reject the null hypothesis that the characteristics in relation to the covariates are not different. Considering the percent bias, the overall matching performance is good. The specific results are shown in <Table 4>, and the balancing is considered to be proper.¹⁶

<Table 4> Balancing Property

Variable	Mean		%bias	t-test	
	Treated	Control		t	p> t
ins2008	.72	.72966	-2.0	-0.11	0.915
age2008	8.9	9.0463	-1.8	-0.10	0.921
size_dum	.42	.4513	-6.5	-0.31	0.755
elec	.02	.01641	1.8	0.13	0.895
newmaterial	.78	.79837	-4.0	-0.22	0.824
bio	.2	.18522	3.5	0.19	0.853
ma_em2008	64.401	59.849	1.4	0.36	0.721
sal_em2008	207.98	213.81	-1.8	-0.13	0.896
profit_~2008	.06816	.04206	1.7	0.80	0.428
rd_emp2008	.21302	.18073	14.2	0.82	0.415
net2008	217.1	228.22	-0.2	-0.04	0.970

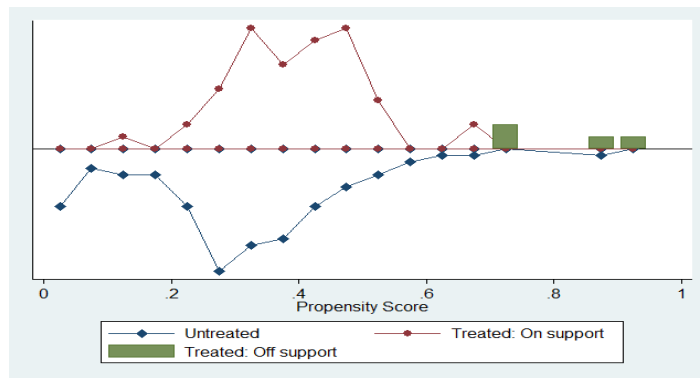
Summary of the distribution of bias					
Percentiles		Smallest			
1%	.2127961	.2127961			
5%	.2127961	1.382751			
10%	1.382751	1.739406	Obs		11
25%	1.739406	1.753805	Sum of wgt.		11
50%	1.838635		Mean		3.548905
		Largest	Std. Dev.		3.907079
75%	4.029568	3.491666			
90%	6.521741	4.029568	Variance		15.26526
95%	14.18579	6.521741	Skewness		2.035357
99%	14.18579	14.18579	Kurtosis		6.16908

Pseudo R2	LR chi2	p>chi2	MeanB	MedB
0.016	2.17	0.995	3.5	1.8

Considering the assumption of the overlap or common support, we can see that the assumption is satisfied as shown in <Figure 1>. The propensity scores of the two groups are between 0 and 1. And by imposing the common support, the treatment observations whose propensity score is higher than the maximum propensity

score of the controls were dropped.

<Figure 1> Propensity Score



Since the supported group and the unsupported group are similar, we can consider the difference of the two groups as the ATT. <Table 5> shows the effect of the government R&D support on the commercialization of developed technology. 101 observations satisfying the assumption of common support were used as the control group and 50 observations satisfying the common support were used as the matched treatment group.

<Table 5> Causal Effect

variable	sample	Treated	Controls	Difference	S.E.	T-stat
bus_s	Unmatched	2.96296296	1.41584158	1.54712138	.698470407	2.22
	ATT	3.08	1.18846135	1.89153865	.939479828	2.01

Note: S.E. does not take into account that the propensity score is estimated.

psmatch2: Treatment assignment	psmatch2: Common support		Total
	Off suppo	On suppor	
untreated	0	101	101
Treated	4	50	54
Total	4	151	155

<Table 6> shows the bootstrap standard error of the estimate of ATT for commercialization of the developed technology. Its T-stat is calculated using this bootstrap standard error. In this case, the ordinary T-stat is biased upward.

<Table 6> Bootstrap results

	Observed Coef.	Bootstrap Std. Err.	z	P> z	Normal-based [95% Conf. Interval]	
_bs_1	1.891539	.9731011	1.94	0.052	-.0157045	3.798782

<Table 7> shows the effect of firms' participation in the R&D support policies on their innovative performance. It shows the mean of the outcome variables for the supported and unsupported firms, the mean difference (ATT), the standard error of the ATT, t-statistics of the ATT, p-value of t-statistics and so on about the ATT.

The government R&D support was found to have significant positive effects on outcome variables such as commercialization of the developed technology, articles, domestic patent applications, registered domestic patents, and new product development. The effects of the government R&D support on registered domestic patents and new product development were not significant in terms of the bootstrap t-statistics.¹⁷

<Table 7> ATT of the government R&D support

(Unit: number)

	Treated	Controls	Difference	S.E.	T-stat	p-values (two-sided)	Bootstrap S.E.	Bootstrap T-stat	p-values (two- sided)
New employees	36.52	29.16	7.36	8.43	0.87	0.39	7.86	0.94	0.35
Sales of new products (million won)	1480.88	332.36	1148.52	901.90	1.27	0.21	873.09	1.32	0.19
Exports (thousand dollar)	10579.26	3438.77	7140.49	7242.51	0.99	0.32	7737.09	0.92	0.36
Commercialization of the developed technology	3.08	1.19	1.89	0.94	2.01	0.05	0.97	1.94	0.05
Articles	0.58	0.00	0.58	0.33	1.76	0.08	0.28	2.05	0.04
Registered industrial property rights	2.64	1.86	0.78	0.67	1.17	0.24	0.91	0.86	0.39
Domestic patent applications piled	3.02	1.02	2.00	0.78	2.56	0.01	0.99	2.03	0.04
Registered domestic patents	2.40	1.15	1.25	0.55	2.29	0.02	0.78	1.6	0.11
International patent application piled	0.26	0.20	0.06	0.17	0.35	0.73	0.16	0.38	0.70
Registered international patents	0.00	0.06	-0.06	0.03	-1.95	0.05	0.04	-1.68	0.09
Prototype development	1.32	0.80	0.52	0.59	0.87	0.39	0.50	1.04	0.30
New product development	1.96	0.54	1.42	0.79	1.8	0.07	0.95	1.49	0.14
Product process improvement	0.40	0.82	-0.42	0.32	-1.33	0.19	0.44	-0.96	0.34
Domestic sales through commercialization (million won)	772.92	94.94	677.98	500.64	1.35	0.18	532.78	1.27	0.20
Export sales through commercialization (million won)	321.16	8.69	312.47	307.96	1.01	0.31	302.55	1.03	0.30

V. Conclusion

This study used the data of 427 observations of small and medium-sized firms established before 2008. This study analyzed the effect of government R&D support policies on a firm's innovative performance focusing on the Gyeongbuk region using PSM. It also noted whether and how much government R&D support improved the firm's innovative performance. It used the propensity score matching to measure the performance of the R&D support policies. Matching has become a popular method to estimate causal treatment effects and it can be applied to diverse policy evaluations. It applies for all cases where one has a treatment, a group of treated individual and a group of untreated individuals (Caliendo and Kopeinig, 2008). PSM tries to decrease the bias due to confounding variables that could be found in an estimate of the treatment (Rosenbaum and Rubin, 1983).

The firm characteristics influencing the participation of the firm in the government R&D support policies are analyzed as the industry of Electronics/Information appliances and New Material/Component and the proportion of R&D employment relative to total employment. As the analysis results show, R&D support policies have positive effects on local firms' innovative performance measured with variables such as commercialization of the developed technology, articles, domestic patent applications, registered domestic patents, and new product development. But R&D support policies do not generate positive effects on local firms' innovative performance measured with variables such as new employees, sales of new products, exports, registered industrial property rights, international patent applications, prototype development, product process improvement, domestic sales through commercialization, and export sales through commercialization. Consequently, the government research and development support policies implemented in the Gyeongbuk region have significantly contributed to the improvement of some aspects of the innovative performance of local firms. So, we can infer that it is rational to expand the R&D support policies and that government needs to design the alternatives to compliment the aspects of performance measured as weak such as prototype development and product process improvement.

This study was limited by the scope of performance that was analyzed. We focused on innovative performance, but did not address the crowding out effect or other unintended effects of government R&D support policies. A more comprehensive performance analysis is needed to gain the necessary understanding to direct future R&D support policy planning.

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NOTES

- 1 Causal indicator variable indicates to which treatment each unit is exposed (Holland and Rubin, 1988).
- 2 After many trials and errors, this study found that the bias is least when using the Kernel matching.
- 3 ins2008. The firms not holding the institutes were coded as 0, and the firms holding the institutes were coded as 1.
- 4 age2008
- 5 size_dum. Small sized firms were coded as 0, and medium sized firms were coded as 1.
- 6 Industry dummy variables include Electronics/Information appliances, New Material/Component, Biological/Herbal Medicine, and other industries.
- 7 ma_em2008

8 sal_em2008

9 profit_sal2008

10 rd_emp2008

11 net2008

12 We need to include the covariates of the year before the years for those the performance was surveyed. But most of the variables of the survey do not include the data for that year, so this study uses the 2008 data. We guess that the bias will not be large because the state of the firm will not change rapidly.

13 The articles include the papers published domestically and internationally, the proceedings of domestic and international conferences.

14 Registered industrial property rights include registered domestic patents, registered international patents, utility model, S/W, design, and the others (such as standard acquisition).

15 We can refer to Long and Freese (2006) for the interpretation of odds ratios.

16 The absolute % biases of most covariates are less than 5. The mean absolute % bias is 3.5, and the median absolute % bias is 1.8. We can refer to Rosenbaum and Rubin (1985) and Grilli Rampichini (2011) for the expression and statistical adaptation of bias.

17 The government R&D support policies were found to have a significant negative effect on the registered international patents. The average number of the registered international patents of the supported firms is zero, and the average number of the registered international patents of the unsupported firms is near zero. And the mean difference is very small. So, we need not give big consideration to the negative effects of the R&D support on the registered international patents.