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The moderating role of external private investment on government-sponsored commercialisation R&D

Zhunwoo Kim[1] • Ohsung Kwon[*2]

[1] *Office of Technology Licensing, Korea Institute of Energy Research (KIER), Republic of Korea*
[2] *Department of Business Administration, Tech University of Korea, Republic of Korea*

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Abstract
The influence of external private investment (EPI) in public R&D is well-known, however, research has yet to understand the significance of it on the success of R&D. We expand upon existing literature by focusing on the effect of EPI in conducting public R&D, and more specifically, suggesting the moderating role of EPI on the commercialisation success with 472 samples from Korean manufacturing firms. Our findings address that EPI positively moderates the relationship between the amount of government fund, the difference of technology readiness level before and after R&D, and the commercialisation success. As a result, this research contributes to a managerial perspective; concluding that public R&D with EPI is both more successful and rewarding.

Keywords: external private investment, R&D subsidy, public R&D, research and business development (R&BD), technology readiness level (TRL)
JEL Classification Codes: O32, O34, O38, G11

1. Introduction

As one of the most innovative countries in the world (Lee et al. 2012), the Korean government conducted diverse policies for the promotion of technology commercialisation to sustain long-term economic growth (Cin et al. 2017); including the legislation of the “Technology Transfer Promotion Act” (2000) (Han 2020).

Amongst these, Research and Business Development (R&BD), a unique Korean program

[*] Corresponding author. E-mail: kwon1@tukorea.ac.kr.

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that differentiates from other countries' policies; is defined as the R&D project focused on technology commercialisation, promoted from the perspective of integrating innovation and market (Jeong et al. 2019). This program enhances Korean industrial competitiveness by directly supporting SMEs through commercialising firms' promising technologies, assisting firms' early overseas expansion and improving the readiness of firms' R&D achievements to the market.

Several studies within R&D subsidy literature highlighted the role and direct effect of government support on firms' innovation. Some researchers found that R&D subsidy is not crowding out private R&D, but rather has a positive effect on it; other studies found the complementary relationship between government R&D and external private investment (EPI) (González & Pazó 2008; Vanino et al. 2019). These studies have depicted government support as a positive influencer for firms' R&D success. As it is difficult for external investors to assess the value of firms' R&D projects, securing government R&D funds seems a meaningful factor for investors (Kleer 2010). Conversely, as the government tends to invest in firms' R&D with an entrepreneur's perspective, EPI becomes a compelling factor in securing government subsidy (Link & Scott 2010).

In the field, external investors have useful information from the market regarding the commercial prospects of R&D, and invest in the R&D projects that are likely to be the most successful. However, little is known about the implication of the real role of EPI in R&D, although it is crucial for determining a firm's strategic innovation activities.

The purpose of this study is to empirically address the importance of EPI, and more specifically, the moderating role of it for the commercialisation success of public R&D, using data from Korean manufacturing firms. From a practical point of view, it is meaningful to examine how EPI exerts a certain moderating effect, namely on the research fund and the developed level of technology, as these are considered key influencing factors on the success of R&D.

2. Data and methods

We examined the post-performance data of R&BD projects from 2013 to 2018. To determine a project's post commercialisation success, the Korean government conducted a survey on all 518 projects in March 2019. As a result, 472 samples were obtained, excluding incomplete observations. In total, approximately 232.3B Korean won (KRW) of government funds were invested in the whole project. The average project fund, duration of R&D and the number of created patents were about 492.2M KRW, 1.3 years and 0.8, respectively.

We used a Probit model to estimate the probability of commercialisation and considered the potential endogeneity. Following Link and Scott (2010), we considered that a firm's existing revenue might be endogenous when the dependent variable is commercialisation success. As this may cause misleading predictor effects on the dependent variable or reverse causality problems, we tried to overcome this issue by applying the instrumental variable approach. We conducted this method with *FIRMSALE(log)* and all other suspected endogenous variables, however, Wald test of exogeneity is not rejected, thus we did not find any evidence of endogeneity (Melkers & Xiao 2012).

Table 1 shows the definition of all variables. We used *dSUCCESS* as our dichotomous dependent variable. This variable denotes whether sales are generated after the R&BD project.

Amongst the R&BD project-related information, variables that could affect the results directly are set as explanatory variables. This is categorised into two groups: the resources invested for the project (*PERIOD, FUND(log), FIRMINV(log)*) and the result of the project (*CREATEDPATENT, TRLEND, TRLGAP*).

Table 1. Definitions of variables

Variables	Definition	References
Dependent		
dSUCCESS	0/1 with 1 indicating commercialisation success	(Link & Scott 2010)
Control		
FIRMAGE(log)	Firm's age in years	(Srivastava et al. 2015)
FIRMSIZE(log)	Number of employees	(Yanadori & Cui 2013)
FIRMSALE(log)	Firm's total sales in KRW	(Link & Scott 2010)
EXISTINGPATENT(log)	Number of firm's existing patents	
RNDINTENSITY	Ratio of firm's R&D expenditure to its sales	(Yanadori & Cui 2013)
AGE	Time elapsed between the end of R&BD and the survey in years	(Link & Scott 2009)
Explanatory		
PERIOD	Duration of project in years	(Link & Scott 2010)
FUND(log)	Amount of the project fund in KRW	(Cin et al. 2017)
CREATEDPATENT	Total number of firm's patents created by the project[1]	(Link & Scott 2010)
FIRMINV(log)	Amount of firm's investment that is related to the project in KRW	(Yu et al. 2016)
TRLEND	Technology readiness level (TRL) after R&BD	(Min et al. 2019)
TRLGAP	Difference in TRL before and after R&BD	
Moderator		
PRIVATEINV(log)	Amount of external private investment in KRW	(Link & Scott 2010)

Source: own elaboration

As discussed in the introduction, our concern is to discover how EPI directly affects a firm's sales after each R&BD project and, if possible, what moderating effect it has on the other explanatory variables. In addition, we believe that there are no issues regarding the causal

[1] This refers to the patents developed in each project, including patents that have been filed but not yet registered, as well as patents that have been registered after filing.

relationship between EPI and firm sales, since EPI was secured while the project was in progress. Therefore, we used the amount of EPI as a moderator.

Lastly, we controlled for firms' existing capability of developing technology before the R&BD project, as firms' commercialisation success partly depends on it. Thus, we considered a one-year time lag between all control variables and the start year of the R&BD project. These firms' financial and patent data were obtained from an available database called 'Korea Enterprise Data', which is one of the most credible companies for providing firms general information.

As some of the continuous variables are highly skewed, we employed logarithmic properties as shown in Table 1. Furthermore, in the table, references to existing studies for each variable are also given.

3. Results

Table 2 presents a summary of statistics and correlations for our main variables. This indicates a limited possibility of multicollinearity.

Table 2. Summary statistics and correlations of main variables (N=472)

	Variable	Mean	SD	1	2	3	4	5	6
1	*PERIOD*	1.324	0.495						
2	*FUND(log)*	8.565	0.299	0.523*					
3	*CREATED PATENT*	0.767	1.737	0.051	-0.016				
4	*FIRMINV (log)*	0.644	2.219	-0.034	0.016	0.191*			
5	*TRLEND*	5.930	2.144	-0.026	0.003	0.120*	0.017		
6	*TRLGAP*	2.502	1.495	0.104*	0.086	0.087	0.051	0.613*	
7	*PRIVATE INV(log)*	1.281	3.157	0.349*	0.521*	0.125*	0.035	0.246*	0.203*

Note: * $p < 0.05$
Source: own elaboration

Table 3 shows estimated results of the probability of commercialisation success. A hierarchical regression analysis was used to ascertain the relative influence of the explanatory variables and the moderating variable in order. The control variables are tested alone in (1), the explanatory variables including moderator are added in (2), and the moderating effect is presented in (3). Here, we find the Pseudo-R^2 gradually increase across the models, from 1.8% to 31.8%. Moreover, the OLS model was also tested in (3) to check if it yields consistent results. In this case, firms' sales in KRW after the R&BD project (*SALE(log)*), were used as a dependent variable and the results remain statistically consistent.

Table 3. Regression results on *dSUCCESS* (Probit) and *SALE(log)* (OLS)

	(1) Probit	(2) Probit	(3) Probit	(3) OLS
Control				
FIRMAGE(log)	-0.179 (0.243)	-0.060 (0.265)	-0.119 (0.272)	-0.378 (0.457)
FIRMSIZE(log)	0.173 (0.175)	-0.135 (0.207)	-0.129 (0.203)	-0.068 (0.363)
FIRMSALE(log)	0.000 (0.029)	0.007 (0.033)	0.008 (0.033)	-0.005 (0.061)
EXISTINGPATENT(log)	-0.178* (0.102)	0.029 (0.126)	0.080 (0.124)	0.231 (0.197)
RNDINTENSITY	0.039*** (0.014)	0.027* (0.014)	0.035** (0.015)	0.074*** (0.025)
AGE	-0.012 (0.053)	0.106* (0.062)	0.023 (0.067)	0.019 (0.107)
Explanatory				
PERIOD		-0.083 (0.204)	0.097 (0.201)	0.185 (0.356)
FUND(log)		0.623* (0.321)	0.234 (0.342)	0.657 (0.646)
CREATEDPATENT		0.114** (0.058)	0.106* (0.057)	0.229** (0.109)
FIRMINV(log)		0.087*** (0.033)	0.072** (0.035)	0.144* (0.075)
TRLEND		0.242*** (0.060)	0.251*** (0.058)	0.203*** (0.075)
TRLGAP		0.299*** (0.057)	0.231*** (0.059)	0.465*** (0.120)
PRIVATEINV(log)		0.059** (0.027)	-3.174** (1.299)	-4.667*** (1.783)
Moderating effects				
*PRIVATEINV(log) * FUND(log)*			0.347** (0.141)	0.524*** (0.201)
*PRIVATEINV(log) * TRLGAP*			0.044** (0.022)	0.059** (0.024)
Constant	-0.749 *** (0.226)	-8.855*** (2.624)	-5.381* (2.827)	-6.863 (5.384)
N	472			
R^2				0.332
Pseudo-R^2	0.018	0.291	0.318	

Note. Robust standard errors are reported in parentheses, *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$
Source: own elaboration

(2) presents the statistical significance of all explanatory variables except *PERIOD*. Notably, the presence of EPI (*PRIVATEINV(log)*) is positively associated with the probability of commercialisation success, which is one of the main findings of this research. Interestingly, we find variables regarding technology readiness level (TRL) (*TRLEND, TRLGAP)* have a positive

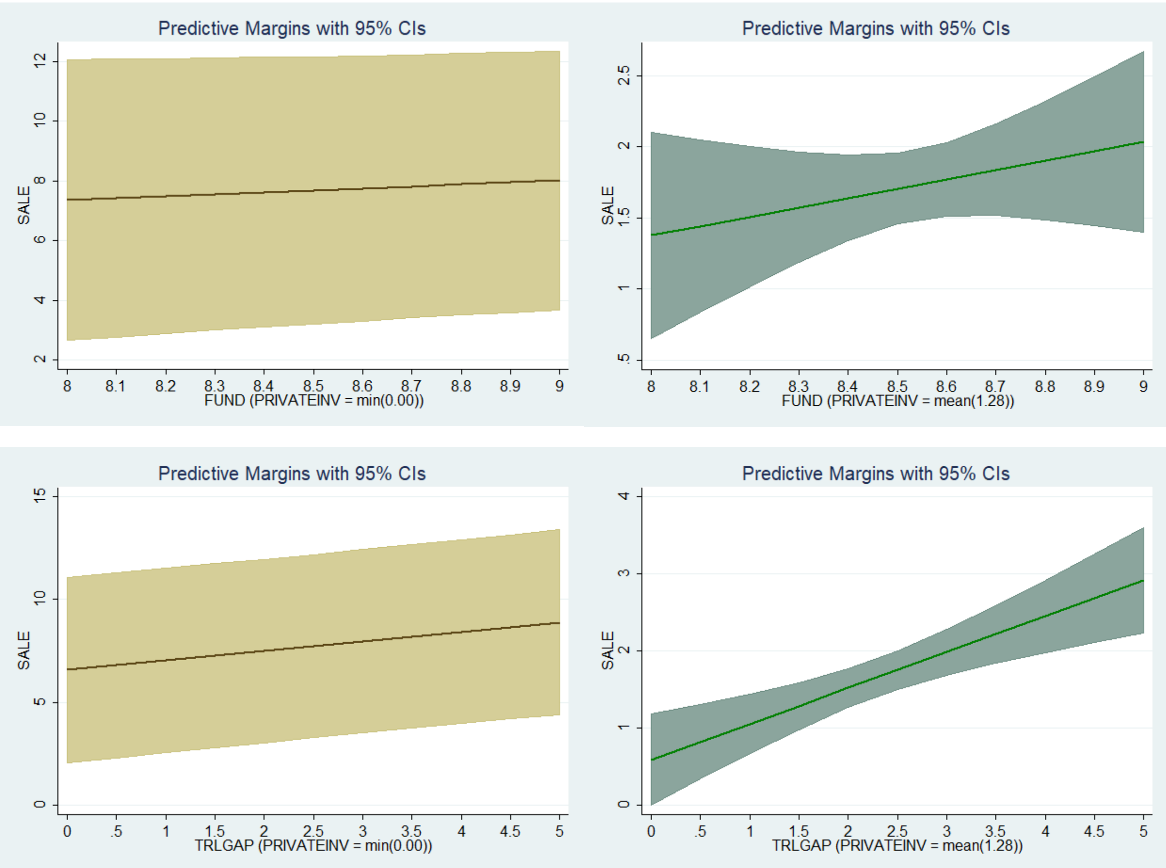
relationship with commercial success.

Especially, the positive relationship between commercial success and *TRLGAP* implies that the likelihood of success is significantly higher when accompanied by substantial technological progress during each project. The significance of this finding is influential as these variables have rarely been used in former studies.

(3) examines the effects of interaction terms. The moderating effect of EPI on the relationship between two main explanatory variables *FUND(log)* and *TRLGAP* and commercialisation success was positively significant. Although the coefficients of EPI are changed, Figure 1 depicts the differences of predictive margins of *FUND(log)* and *TRLGAP* cases when EPI values are minimum (0.00) and mean (1.28), respectively. In other words, it is expected that the amount of R&BD fund and the level of technology developed during the project generally exert significantly positive effects on the success, additionally, it can be found that projects with EPI intensified this effect.

From the OLS model in (3), the maximum VIF is 5.84, indicating no significant multicollinearity issue. All models were estimated with robust standard errors to allow heteroscedasticity in the errors.

Figure 1. Predictive margins on *SALE(log)* with 95% CIs



Source: own elaboration

4. Concluding remarks

This study is motivated by former empirical literature about the role of EPI in government-sponsored R&D projects; and the need to assess how this is combined with other factors to effect commercialisation success. The key finding of this study is that the presence of EPI in R&D projects has a positive relationship with commercialisation success. More specifically, our results empirically provide important findings, demonstrating the positive moderating role of EPI. As EPI becomes larger, R&D fund and the difference of TRL become more prominent factors for commercial success.

This research also boasts a contribution to two areas. From a practical perspective, our study provides empirical evidence to be considered in the distribution of the government's R&D resources to policymakers. Since the government's role in investing R&D is to redirect limited resources, return on investment should be considered first (Link & Scott 2010). Notably, from our research, R&D with EPI is more successful and rewarding, indicating that the government should focus on projects with EPI. Moreover, this study offers a rare insight into firms' successful commercialisation, suggesting that firms should care about technical development and raising funds for conducting R&D. In other words, they should focus on creating patents, improving TRL, investing their own funds, and attracting external investment in addition to a government subsidy.

Our main limitation is that the dataset for this study is limited by its narrow focus on Korean firms, meaning that difficulty arises when the results are attempted to be generalised. The other limitation is that the commercialisation success might depend on a larger set of factors than those examined in this study, meaning that there may be an endogenous issue that we did not predict. Therefore, future research should consider creating a model with more variables and moderators, so that a more robust relationship between variables, moderators and the results could be discovered.

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