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Article

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Unleash liquidity constraints or competitiveness potential: The impact of R&D grant on external financing on innovation



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ABSTRACT

This paper uses Korea's internal data on R&D programs to analyze how the receiving of R&D impacts the amount of subsequent external financing for technological innovation received by R&D firms. We address sample selection and endogeneity issues that arise when estimating the impact of R&D policy by utilizing a matching method using unique features of Korea's R&D grant programs. Our empirical results show that firms that receive R&D grants further receive 22%–32% less external financing compared to those who do not receive R&D grants, though there are some differences in the statistical significance of the results based on the specification of the regression model. This is consistent with the view that R&D grants reduce firms' liquidity constraints, or that government support effectively crowds out funding from the financial market.

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1. Introduction

Many countries invest a significant amount of public funds to R&D in order to foster innovation. There have been some studies that argue that it is the government's role to enact policies to further boost investment in the R&D sector. The seminal works by Nelson (1959) and Arrow (1962) show that research and development (hereafter R&D) activities (including discovery of new technologies and knowledge, development of new services or products, and significant improvement of existing services or products) are under-invested by the market due to their non-rival nature as public good. That is, while R&D has a positive external effect on the society in the form of advances in technology, expansion of knowledge, and enhancement of personal and business productivity, the market does not provide as much R&D activity as is socially optimal. These problems provide an important basis for the public sector to support private R&D activities.

Many empirical studies have been conducted on the impact of innovation on the technological development of firms in various geographical regions, and these discussions confirm that innovation has a positive effect on firm performance, which measures various outcomes. Sánchez-Sellero, Sánchez-Sellero, Sánchez-Sellero and Cruz-

González (2015) find that innovations in product, processes, and R&D activities (especially external R&D activities) help to improve employees' knowledge absorption and productivity which, in turn, have a positive impact on firm performance. They also confirm that activities related to internal organization or external collaboration for innovation contribute to increase productivity. Triguero, Córcoles and Fernández (2020) analyze the impact of open innovation (OI) strategies on employment by breaking down Spanish firms by type of external partner. They support that open strategies have a positive impact on employment growth.

In their study of Finland firms, Aldieri, Makkonen and Vinci (2021), show that there is a statistically significant positive employment effect of local innovation activities and knowledge dissemination in other regions only on the demand for high-skilled employees. Lööf, Larjani, Cook and Johansson (2015) apply a dynamic approach to a disproportionate panel of 8516 Swedish firms observed over a 12-year period and find that among firms with permanent presence in the export market, persistent innovators had an annual productivity growth rate of 0.5 percentage points higher than that of non-innovative exporters.

Using a sample of UK firms between 1988 and 1992, Wake-lin (1998) finds that R&D intensity had a positive and significant effect on productivity growth. Storey and Hughes (2013) show in an empirical analysis of 105 UK service companies that a good corporate innovation culture helps build service innovation capabilities to

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achieve new service development outcomes. [Nemlioglu and Mallick \(2017\)](#) use data from UK firms for the period 1992–2014 and find that firms that focus on R&D activities along with better management practices benefit favorably.

[Baldwin and Johnson \(1996\)](#), using data on Canadian firms, find that innovative firms place greater emphasis on management, human resources, marketing, financing, government programs and services, and production efficiency. They also confirm that innovative companies perform more successfully. Using detailed firm-level data of the United States, [Burrus, Graham and Jones \(2018\)](#) find the relationship between a region's level of innovation and publicly traded firms' performance. They confirm that innovation activity indexed by a patent index is positively correlated with revenue and profit growth, while technological creativity measured using the tech sector employment index is associated with process improvement and increased net profit. In a longitudinal study, [Artz, Norman, Hatfield and Cardinal \(2010\)](#) find that patents and product innovations obtained in various industries in the United States and Canada have a significant positive impact on firm performance.

[Odei, Stejskal and Prokop \(2021\)](#) analyze 1820 firms in 10 European countries using the Community Innovation Survey dataset to determine the significant impact on innovative outcomes from the perspective of radical and progressive SMEs and large enterprises to find that the region's progressive and radical innovators effectively absorb new knowledge that improves new product development. [Griffith, Huergo, Mairesse and Peters \(2006\)](#) find that product innovation is more effective and productive in France, Spain and the United Kingdom, whereas process innovation only helps increase productivity in France. Using a sample of French firms in the manufacturing and service industries, [Peters \(2008\)](#), through a study of German firms, argues that when firms' ability to innovate improves, their performance improves. In other words, the firm's innovation contributes to increasing the labor productivity of the firm, confirming that the firm can achieve more economic benefits.

In addition to the study of the impact of these innovations on a firm's technological progress and productivity, studies have also been conducted on the impact of the innovation on a firm's financial health. Public funding of private R&D activities strengthens firm's financial health and increases their reputation in the financial market, thereby affecting their ability to receive further investment from the private sector. Within this context, our paper is most closely related to two major strands of study on the economic impact of increased investment in the R&D sector. The first is a series of papers that investigate how R&D subsidies affect a firm's R&D investment. [Czarnitzki \(2006\)](#) and [Takalo and Tanayama \(2010\)](#) argue using theoretical models that there is a 'resource effect' that reduces external R&D investment, as the R&D grant provides the firm with the necessary liquidity. [Lach \(2002\)](#) argues that the government reduces demand for investment from external sources by selectively allocating grants to the highest-potential firms, who would likely attract the most private investors. On the other hand, [Feldman and Kelley \(2003\)](#), [Feldman and Kelley \(2006\)](#), and [Meuleman and De Maeseneire \(2012\)](#) argue that an R&D grant has a positive effect on external investment by sending a signal to the market on the quality of the firm's technology. [Lerner \(2002\)](#) argues that the receipt of public support works as a 'certification effect' that certifies the value of the firm.

The next strand of literature relevant to our study deals with the financial side of the impact of private sector R&D support and is focused on whether support crowds in or crowds out firms' internal R&D expenditure. [Wallsten \(2000\)](#) finds that firms that received SBIR programs reduced their internal R&D expenditures compared to those who did not, while [Busom \(2000\)](#) also showed that in a sample of Spanish firms that received R&D support, grants completely crowded out internal investment in 30% of the cases. On the other hand, [Klette, Møen and Griliches \(2000\)](#) find that in a sample of Norwegian firms, targeted R&D support increased firms' R&D

expenditure. In a survey of 77 firm level studies, [Zúñiga-Vicente, Alonso-Borrego, Forcadell and Galán \(2014\)](#) confirm that the existing empirical studies show mixed results as to whether the subsidies provided by the public sector for the firm crowds out internal private R&D investments. [Becker \(2015\)](#) examines the existing literature and suggests that earlier literature ([David, Hall and Toole \(2000\)](#); [García-Quevedo \(2004\)](#)) shows mixed results of whether government subsidies crowd in or out of private R&D.

There have also been some recent studies conducted with interest in firm size, characteristics, and financial institutions. [Dimos and Pugh \(2016\)](#) note that it is unclear whether R&D subsidy clearly crowds out the firms' internal R&D investments or has additional effects. They emphasize that based on these results, unobserved corporate traits have a significant effect on these heterogeneous effects. [Hottenrott, Lopes-Bento and Veugelers \(2017\)](#) identify the impact of R&D expenditures by dividing research grants and development grants in order to analyze the impact of the type of support on the activities of firms. They suggest that the target system is more effective at triggering R&D than the mixed system, based on the analysis that research grants have a positive effect on research investments but not directly on development grants. [Kim, Lee and Kim \(2016\)](#) investigate the various effects of external finance (bank loans, issuance of stocks and bonds) on technological innovation activities of domestic listed companies using Korean data. They find that indirect external financing has a negative impact on technological innovation activities, while direct external finance through securities issuance has a positive effect. [Brown et al. \(2009\)](#) show that cash flows and issuance of public capital were very important for young American companies during 1990–2004 but had little impact on mature firms' R&D investment. [Moon \(2021\)](#) argue that firm size and subsidy conditions have effects on firms' innovation type.

Recently, there has been a heightened interest on the impact of R&D investment in the form of government subsidies and corporate VC investments on external financial activities (both banks and venture capitalist). [Mann \(2018\)](#) confirms that innovation firms leverage debt financing and financing using patent as collateral. [Robb & Robinson \(2014\)](#) find that external bank financing is still an important financing source for emerging small firms that lack collateral. [Martí and Quas \(2018\)](#) study the effect of participative loan on SME's access to external financial debt and find that the loan has a positive effect on receiving external financial debt and that this effect is stronger for smaller firms with high-tech sector. [Li, Lee and Wan \(2020\)](#) show in the context of the Chinese high-tech industry that while R&D subsidies targeted at firms positively impact the firms' short-term debt financing and equity financing, there is no effect on their long-term debt financing.

The study of how government subsidies affect a firm's ability to receive VC funding is also an important trend that has developed in the literature. [Lerner \(2000\)](#) finds evidence that obtaining R&D grants positively impacts a firm's chances of attracting venture capital. [Howell \(2017\)](#) provides an empirical analysis of energy-related firms supported by the SBIR program and their connection to investment from venture capital. She shows that the probability of receiving investment from a venture capital firm is twice as high for firms supported by the SBIR program than for firms with no support from the initial phase of the SBIR program. However, these studies focus on the impact on VCs in small businesses, start-ups, or in specific tech sectors, taking into account the general operational behavior of VCs. [Davila, Foster and Gupta \(2003\)](#) identify the impact of venture capital (VC) funding on startup growth. Their study confirms that corporate employment increases before receiving funding from the VC and further increases after receiving funding. [Li, Chen, Gao and Xie \(2019\)](#) find that the government's support of innovative entrepreneurial firms in China has a positive certification effect on financial activities, including VC funding from outside. [Zhao and Ziedoni \(2020\)](#) show that startups in Michigan that obtain R&D loan is 20–30% more likely

to survive in the 4 years following the issuing of the loan and that the loan further stimulates follow on investments for younger firms.

Korea, which operates the program targeted for this study, places great emphasis on R&D; its Constitution states that one of the most important roles of the public sector is the promotion of technology through support for R&D. The government currently allocates more than 5% of the total annual budget to supporting private-sector R&D activities, the highest per capita expenditure not only in Asia but also among OECD countries (OECD 2018). OECD report shows that the largest portion of Korea's R&D subsidies is composed of direct R&D grants, which, as of 2017, totaled about \$18 billion. The government has a set of support regulations and project selection rules that apply to all departments, but detailed operation is left to each ministry. All firms that have passed the common minimum qualification requirements that apply globally (i.e. default risk, criminal activity, and non-compliance with government contracts) can apply for R&D grants.

By providing R&D grants, the Korean government provides important information about firms and in turn exerts great influence on the market. The information that is collected in evaluating the projects of various firms for awarding grants helps alleviate the free rider problem faced the financial market and allows investors to better screen the potential and the quality of R&D projects undertaken by these firms. The fact that the government receives countless applications for R&D grants and is thereby able to collect an immense amount of information about the applicant firms provides a valuable source of data for private investors. This is one of the points made by Lerner (2002) in arguing that government officials are better able to overcome problems related to inadequate information compared to private investors. He claims that while government experts are able to have great insight about the potential of certain technologies or firms, investors whose basis of analysis is solely financial statements has certain informational limitations. Furthermore, since investments into R&D projects tend to be risky, the fact that such a project was able to be approved for a grant after going through a rigorous evaluation by an agency with high standards signals that the project may be profitable for private investors.

The Korean government's approval process for R&D grant applications are similar that of other governments. All firms that have passed the common minimum qualification requirements that apply globally (i.e. extremely high default risk, criminal activity, and non-compliance with government contracts) can apply for R&D grants. The most important factor for awarding R&D grants is the adequacy of the business proposal and the evaluation is performed by an evaluator among a pool of experts. Firms submit an application containing the purpose of the project, the size of the project, and the operational plan. The government then undertakes a qualitative evaluation of the applicant's eligibility which takes into consideration the purpose of the project, its growth potential, and innovativeness.

This study focuses on analyzing the impact of government support on firms receiving innovation related investments in the financial markets after they are supported. We use Korea's internal data to empirically identify these impacts. Our study makes some important contributions to the existing literature. First, we analyze the effect of R&D grants on external investment receipt on innovation using Korean program. This lends empirical support for existing hypotheses about the impact of R&D on firms' external financing. In particular, Korea has the highest per capita R&D grant expenditure among OECD countries, and analyzing the effects of the program on an industry-wide scale will make an important contribution to the existing literature. In addition, studies so far focus on analyzing the impact of support for SMEs or firms in specific industries. On the other hand, our study targets Korean R&D program that provide large-scale support to the entire industry and analyzes its effects on receiving external financing to contribute to the existing study.

Our paper proceeds as follows. Section 2 describes the data and variables. Section 3 shows empirical strategy and Section 4 describes empirical findings and the results. Section 5 concludes with a summary of our findings and its policy implications.

2. Data and variables

In this section, we analyze the impact of government subsidies on the future likelihood of receiving external financing from using internal data provided by the Korean government for the first time. In particular, we use two empirical approaches to address selection bias and endogeneity issues that are often present in estimating the effects of government R&D policies. As Jaffe (2002) notes, the unobserved characteristics such as the characteristics of the country in which the company is located, the regional characteristics, and the unique attributes of firms that receive R&D grants will form a strong positive correlation with innovation performance. The unobserved variables of firms that receive grants and firms that do not receive grants may be different, and this difference may result in different outcomes. Therefore, identifying biases is important for accurate estimation of policy effects.

While it is difficult to completely overcome such limitations, we are able to alleviate these issues in some ways. As a way to reduce potential selection bias, we use the propensity matching score (PSM) method. The PSM method compares the treatment group with a control group constructed to have the closest characteristics to the treatment group, and estimates the treatment effect of receiving government grant. The first step is to obtain the propensity score, which is the probability of receiving government grant based on the characteristics of firms. Then, the treatment group and the non-treatment group are matched using the propensity score. The average treatment effect is then estimated by the weighted mean outcome difference between the treatment group and the non-treatment group.

The data used for empirical analysis is composed by merging three sets of data. The main data set is confidential government data, which is a list of all firms applying for R&D grant to the Ministry of Industry of Korea. This data includes general information such as the names and identifiers of all firms applying for R&D grant from 2009 to 2013, the number of employees, industry, and whether the firms is large or small.

The firm's financial information comes from one of the largest credit rating companies in Korea. Using the firm's identification number, we match information such as sales, debt ratio, and R&D intensity (ratio of internal R&D investment to sales). The age of a firm is also an important indicator of whether the firm is subsidized by the government or invested externally. Therefore, we acquire additional internal data and match them with the constructed data.

In addition, the financial health of the firm at the time prior to filing may play an important role in applying for and being approved for public grants. In order to identify the treatment effect by alleviating the impact of financial factors on receiving public subsidies, we acquire internal data including net income, total assets, credit rating, and liquid assets a year before a firm applies for the subsidy and merge it with the existing data. In addition, to take advantage of the data on company location, we use the company identifier to extract the location of the local headquarters to match the current address or otherwise merged the location information based on the current address. Data on location is recorded as the district in which the company is located, which is a broader concept than a town and is the smallest unit of administrative and tax levels.

Firms' innovation investment and financing receipt data uses the internal data of the government. There is a system that is similar to the disclosure system in the stock market. Through this system, firms inform the government that they have received financing (including direct investment and loan) from external financial institutions for

Table 1
Summary statistics.

	Mean	S.D	min	max	skewness	kurtosis	Description
INNO	0.1		0.0	1.0	–	–	Innovation Financing Recipient (1=Receive external financing, 0=otherwise)
SELECT	0.3		0.0	1.0	–	–	Grant Recipient (1=Receive Grant, 0=otherwise)
GRANT	147.4	390.0	0.0	10,000.0	7.0	102.6	Grant amount
EMP	388.8	3646.1	5.0	9304.0	10.0	118.9	Number Of Employees
SALES	409,347.3	4,285,021.8	0.0	46,155,916.0	22.8	604.7	Revenues from the year before the government grant application
PROFIT	1949.7	40,576.4	–614,839.4	1,642,451.3	25.6	847.3	Net profit from the year before the government grant application
ASSET	20,976.1	301,981.3	–44,735.5	11,426,946.0	22.9	611.8	Total assets held by the firm one year before the government grant application
LIQUIDITY	2947.8	65,594.9	–5,058,836.5	3,720,842.5	17.7	2091.7	Liquidity assets held by the firm one year before the government grant application
CREDIT	3.06	1.7	1.0	10.0	2.5	7.9	Credit score of the firm (AAA to D that are converted to 1–10)
DEBT	296.8	10,145.0	–101,990.2	1,746,085.0	161.5	27,570.9	Debt Ratio (%)
RDINVEST	94.3	5254.3	0.0	732,727.3	120.8	16,031.3	R&D Intensity (Internal R&D Investment/Revenue) (%)
AGE	13.9	9.1	1	94.0	2.2	11.3	AGE of firms
Log(EMP)	3.3	1.5	0.0	9.1	0.9	4.3	
Log(SALES)	8.2	2.3	–2.4	17.6	0.2	4.3	
Log(PROFIT)	7.0	2.0	–0.8	14.3	0.6	4.3	
Log(ASSET)	9.1	2.0	2.0	16.3	0.6	4.1	
Log(LIQUIDITY)	8.1	1.9	–0.4	15.1	0.5	4.4	
Log(CREDIT)	1.7	0.4	0.0	2.3	–1.1	4.7	
Log(DEBT)	4.8	1.2	–4.6	14.4	–0.7	7.6	
Log(RDINVEST)	1.9	1.6	–4.6	13.5	–0.1	5.2	
N	21,314						

R&D grant sample is comprised of 5 years, which span from 2009 to 2013 INNO recipient sample is comprised of 5 years, which span from 2012 to 2016.

Variables with missing Std. Dev. are dummy variables.

Monetary units are in 1000,000 Korean won, which is approximately equivalent to 1 thousand US dollars.

innovation activity, and the government reviews and discloses this information to the public. A major purpose of this system is to provide information to the public that the firm has sufficient capabilities and skills to receive investment from the market. In order to induce the provision of such information, the government provides firms disclosing receipt of financing with fast-tracked listing in the stock market and patent examination and offers tax benefits to R&D activities funded through the investment. We use the data on firm identifier to match firms that received government grants to their investment receipt status in the following three years (2012–2016). Firms' financial information and age information are obtained through the Korean Information Service (KIS) Value Library.

The construction of this data set contributes to the existing literature in a number of ways. First, our study is the first paper which utilizes comprehensive data on R&D support programs in Korea, where government support for R&D plays a significant role. In 2017, Korea's R&D budget was about 19 billion dollars, and the amount supported by the Ministry of Industry was about 5 billion dollars, which accounts for more than 30% of the total budget. The fact that most of the support for firms is given by the Ministry of Industry shows that this data is suitable for analyzing the effects of government grant on the industry. In addition, we built a firm level data of all firms applying for the government grant (including all selected an unselected firms) for the first time, and this data can be used to estimate the effect of government grants at the firm and industry levels.

We are also able to analyze the effect of the government grant on firms' receipt of external financing by using the characteristics of Korea's disclosure system. The strength of the data used in our paper is that they are collected systematically. The government is required by law to collect relevant data, and the probability of a missing data in this process is significantly lower than manually collected data. In addition, our data overcomes the limitations of existing study by using data on support for a full range of firms in the seven categories of industries. Thus, our data takes advantage of an institutional idiosyncrasy to overcome the limitation of existing data. Given the incentives of the disclosure system used by our paper, firms with external investment are expected to release the information, which can be effective in reducing the problem of missing data. Based on this data, we are able to contribute to the existing literature on the impact of

government grants on firms' financing constraints and also test whether government grants crowd out or crowd in private investment. Also, using data on investments in innovation-related activities other than firms' other activities effectively identifies identification by minimizing the impact of firms' other factors, behavior, and projects.

Table 1 reports summary statistics of key variables. The data contains information on 21,314 firms applying for government grants from 2009 to 2013 and has information on whether they have been externally financed within three years after applying for a government grant. The firm's industry is classified on the basis of six technologies; IT (Information Technology), BT (Bio Technology), NT (Nano Technology), ST (Space Technology), ET (Environment Technology), CT (Culture Technology).

The INNO variable indicates whether the firm has received Innovation Financing. The SELECT variable is a binary variable indicating whether the firm has received R&D subsidies from the government. This means that about 30% of the firms applied for the subsidy received support. GRANT shows the amount of support received. EMP is the number of employees at a firm when at the time when the firm applies for a grant. SALES shows the revenues from the year before the government grant application, and PROFIT shows the net profit from the year before the government grant application. ASSET is the total assets held by the firm one year before the government grant application, and LIQUIDITY is the liquid assets held by the firm one year before the government grant application. In addition, CREDIT represents a firm's credit rating in terms a score between 1 and 10. The DEBT and RDINVEST variables represent the firm's debt ratio and internal R&D investment ratio. In selecting variables, we take into consideration that SALES, PROFIT, ASSET, LIQUIDITY and CREDIT are financial factors that affect both the firm's receiving subsidies and external financing. In addition, we also take into consideration the fact that the firm's debt ratio, internal R&D investment ratio, number of employees and business power are factors that affect the firm's innovation performance. Table 1 also shows the skewness and kurtosis of the log-transformed variables. Excluding the log-transformed CREDIT variable, skewness has a range between –1 and 1, and kurtosis has a range between 4 and 5. The fact that the kurtosis is slightly larger than 3, which represents the standard normal

Table 2
Estimation using probit and LPM - Effects of R&D Grant receipt on External Financing Receipt.

	(1)	(2) (3) Probit	(4)	(5)	(6) (7) LPM	(8)	
SELECT	-0.0451*** (0.0108)	-0.0136 -0.0618*** (0.0153) (0.0157)	-0.0132 (0.0223)	-0.0541*** (0.0118)	-0.0476*** -0.0444*** (0.0127) (0.0123)	-0.0375*** (0.0131)	
GRANT		-6.79e-05*** (2.61e-05)	-0.000106*** (3.83e-05)		-1.23e-05 (9.08e-06)	-1.43e-05 (9.22e-06)	
log(EMP)	0.0141 (0.00888)	0.0153* (0.00889)	0.0237* (0.0136)	0.0250* (0.0136)	0.0138* (0.00795)	0.0146* (0.00797)	0.0133 (0.00851)
log(SALES)	-0.00672 (0.00887)	-0.00575 (0.00891)	-0.0101 (0.0138)	-0.00888 (0.0138)	0.00307 (0.00886)	0.00356 (0.00886)	0.00439 (0.00939)
log(DEBT)	0.00712 (0.00694)	0.00663 (0.00690)	0.0102 (0.00969)	0.00954 (0.00958)	0.00506 (0.00729)	0.00501 (0.00728)	0.00640 (0.00759)
log(RDINVEST)	0.00934* (0.00482)	0.0104** (0.00486)	0.00443 (0.00763)	0.00599 (0.00770)	0.00906** (0.00435)	0.00931** (0.00435)	0.00513 (0.00482)
log(Preasset)	-0.0347*** (0.00709)	-0.0338*** (0.00704)	-0.0267*** (0.0100)	-0.0241** (0.00987)	-0.0392*** (0.00773)	-0.0389*** (0.00773)	-0.0298*** (0.00842)
log(Preprofit)	0.0189*** (0.00615)	0.0188*** (0.00615)	0.0254*** (0.00900)	0.0259*** (0.00893)	0.0213*** (0.00584)	0.0210*** (0.00585)	0.0180*** (0.00603)
log(Preinliquidity)	-0.00832* (0.00494)	-0.00823* (0.00495)	-0.0190** (0.00742)	-0.0187** (0.00740)	-0.00591 (0.00523)	-0.00569 (0.00523)	-0.00659 (0.00535)
log(Precredit)	-0.00547 (0.00436)	-0.00519 (0.00435)	-0.0103 (0.00659)	-0.00979 (0.00652)	-0.00120 (0.00426)	-0.00125 (0.00426)	-0.00377 (0.00445)
INDUSTRY DUMMY(BT)			0.0963 (0.510)	0.111 (0.508)			
INDUSTRY DUMMY(CT)			0.0423 (0.437)	0.0535 (0.435)		-0.0265 (0.0574)	-0.0272 (0.0573)
INDUSTRY DUMMY(ET)			0.0829 (0.341)	0.0944 (0.340)		0.000113 (0.0157)	0.000261 (0.0157)
INDUSTRY DUMMY(IT)			0.0305 (0.256)	0.0416 (0.255)		-0.0152 (0.0142)	-0.0137 (0.0142)
INDUSTRY DUMMY(NT)			0.0806 (0.172)	0.0850 (0.171)		0.0468** (0.0205)	0.0465** (0.0205)
INDUSTRY DUMMY(ST)						-0.0489 (0.0551)	-0.0481 (0.0551)
Age	-0.0385*** (0.00886)	-0.0403*** (0.00892)	-0.00151*** (0.000511)	-0.00121*** (0.000451)	-0.00154*** (0.000503)	-0.00156*** (0.000503)	-0.00162*** (0.000511)
Constant					0.240*** (0.0497)	0.230*** (0.0502)	-3.101*** (1.064)
R-squared					0.043	0.044	0.164
Year-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Year and Location fixed effects included.

distribution, shows that the distribution of our data has heavier tails compared to the standard normal distribution.

3. Empirical strategy

3.1. Simple probit regression

Table 2 shows how receiving government support affects subsequent external financial access through a simple probit model and a linear probability model (LPM). Columns (1) and (3) show that receiving government support reduces the likelihood of receiving subsequent external financing. In particular, the table shows that the higher the asset and liquidity before the government support, the lower the probability, and the higher the net profit, the higher the probability. This proves that the firm's net profit is regarded as an important indicator of market competitiveness. In addition, the table shows that the higher the firm age, the lower the probability. This suggests that as the firm's age increases, the firm is more likely to utilize its internal resources. An analysis that considered the amount of support at the same time as whether it received government support (columns (2), (4)) shows that the higher the amount of support, the less likely it is to receive subsequent financing. Estimation through LPM also shows similar results to the Probit model.

3.2. Propensity score matching

Policy analysis is frequently complicated by the issue of sample selection. In other words, receiving a grant from the government may be correlated with other firm characteristics that also affect the outcome. Therefore, we use the propensity score matching method to reduce the potential selection bias in the estimation of policy effects. The propensity score matching method is a technique for estimating the effects of treatments or policies and is based on consideration of covariates that may affect treatment. The probability of a particular unit belonging to a treatment group is obtained through the observed characteristics (this is called a propensity score), and this is used to balance the covariates of the treatment group and the control group to reduce the expected selection bias. The first step is to obtain the propensity score, which is the expected probability of receiving an R&D grant based on firms' observed characteristics, such as debt ratios, number of employees, age, sales, and R&D intensity. In the next step, the treated and untreated firms are matched based on the propensity score. The average treatment effect is then estimated by the weighted average difference of the outcomes (external financing receipt) of the two matched groups.

Denoting the outcome in the presence and absence of the policy treatment by $INNO_1$ and $INNO_0$, where $INNO$ is the outcome status

Table 3
Estimation using Probit Model**.

VARIABLES	(1) Select
log(EMP)	0.172*** (0.0599)
log(SALES)	0.237*** (0.0644)
log(DEBT)	0.00159 (0.0481)
log(RDINVEST)	0.249*** (0.0316)
log(Preasset)	0.161*** (0.0542)
log(Preprofit)	0.0114 (0.0390)
log(PreInliquidity)	-0.0214 (0.0349)
log(Precredit)	0.0232 (0.0299)
Age	-0.000991 (0.00391)
INDUSTRY DUMMY(BT)	-4.181*** (1.060)
INDUSTRY DUMMY(CT)	-3.534*** (0.935)
INDUSTRY DUMMY(ET)	-2.937*** (0.710)
INDUSTRY DUMMY(IT)	-1.997*** (0.536)
INDUSTRY DUMMY(NT)	-1.115*** (0.386)
INDUSTRY DUMMY(ST)	-
Constant	0.0820* (0.0457)
R-squared	0.164
Year-Fixed Effects	Yes
Region-Fixed Effects	Yes

Standard errors in parentheses.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

($INNO=1$: received external financing; $INNO=0$: otherwise), and where $SELECT$ is the treatment status ($SELECT=1$: treated (got government grant); $SELECT=0$: untreated), the average treatment effects for the treated (ATT) can be defined as

$$ATT = E(INNO_1 - INNO_0 | SELECT = 1) = E(INNO_1 | SELECT = 1) - E(INNO_0 | SELECT = 1) \tag{1}$$

In Eq. (1), $E(INNO_1 | SELECT = 1)$ can be estimated with a simple mean of the outcome ($INNO$) in the group of firms that are subsidized, but $E(INNO_0 | SELECT = 1)$ is unobservable. In order to overcome this

problem, $E(INNO_0 | SELECT = 1)$ needs to be substituted by referring to a suitable “counterfactual” of untreated firms. More precisely, in order to control for selection bias on observables, the difference in outcome between the two groups needs to be exclusively due to the policy intervention. One way to achieve this is by choosing untreated firms in such a way that they match treated firms in terms of their propensity score, $Pr(SELECT = 1 | X(or)P(X))$. In other words, untreated firms are to have the same probability of being funded than treated ones, given the set of pre-treatment characteristics, X , which are supposed to affect both the treatment and the outcome. The PSM estimate of the ATT is given by

$$ATT_{PSM} = E_{P(X) | SELECT=1} \{E[INNO_1 | SELECT = 1, P(X)] - E[INNO_0 | SELECT = 0, P(X)]\} \tag{2}$$

We use the Kernel matching and the Caliper matching method for matching. The first approach is to generate a synthetic counterfactual for a particular treated firm by a kernel-weighted average of the characteristics of all matched untreated firms. The closer the propensity score of the untreated firm to that of the treated firm, the higher the weight assigned to that untreated firm in constructing the counterfactual case of the treated firm. The Caliper method matches the treated firm with a maximum of n -nearest untreated firms and applies the same weighting. We apply $n = 5$ in this study and also check the case of $n = 1$ to check for robustness.

4. Empirical findings

The propensity score can be a good predictor of treatment because the explanatory variables we use are key variables that the government use to screen R&D grants. By pairing similarly situated firms as treatments and controls in this manner, the PSM model reduces the selection bias due to unobserved variables.

As a first step, we estimate the impact of the firm’s observed characteristics on the probability of receiving government R&D grants. The predicted probability is used as the propensity score in the PSM method. In order to alleviate the selection bias that may occur, we used financial variables such as sales, creditworthiness, liquidity and sales that can affect the selection. We estimate using the probit models, with the results shown in Table 3. As the table shows, the probability of receiving a grant from the government increases as the firm’s number of employees, sales, internal R&D intensity, and asset increase. This implies that the government has a tendency to choose firms with larger size, internal R&D investment, asset, and less debt.

Table 4 shows the resulting sample size, the mean of all covariates, and the median standardized difference based on different matching methods. The mean standardized difference in covariates across treatment and comparison groups in the original sample is 41.1 percent. Of the matching and weighting strategies, kernel

Table 4
Sample Size, Mean, and Median Standardized differences across covariates in Original and Matched.

	Total Sample Size	Number of Treated Observations	Number of Comparison Observations	Mean Standardized Difference in Covariates (%)	Median Standardized Difference in Covariates (%)
Original Sample	21,314	14,913	6401	41.1	28.2
Kernel matching, bandwidth=0.05	21,226	14,897	6329	2.1	2.0
Kernel matching, bandwidth=0.01	21,212	14,897	6315	2.4	2.3
Caliper, bandwidth=0.05 with $n = 5$	19,674	13,455	6219	3.4	2.4
Caliper, bandwidth=0.01 with $n = 5$	19,251	13,134	6117	3.7	2.5
Caliper, bandwidth=0.05 with $n = 1$	19,533	13,314	6219	4.4	3.4
Caliper, bandwidth=0.01 with $n = 1$	19,134	13,017	6117	4.7	3.5

Table 5
Test of balancing of covariates–Kernel Matched Sample.

Kernel Matched Sample (Bandwidth 0.05)								Kernel Matched Sample (Bandwidth 0.01)							
		Mean				t-test				Mean				t-test	
Variable	Unmatched/Matched	Treated	Control	%bias	%reduct bias		<i>p</i> > <i>t</i>	Variable	Unmatched/Matched	Treated	Control	%bias	%reduct bias		<i>p</i> > <i>t</i>
log(EMP)	U	5.4702	4.5829	80.9		15.53	0	log(EMP)	U	5.4702	4.5829	80.9		15.53	0
	M	4.9467	4.9081	3.5	95.7	1.15	0.251		M	4.9467	4.9351	1.1	98.7	0.34	0.732
log(SALES)	U	11.273	10.127	77.9		14.76	0	log(SALES)	U	11.273	10.127	77.9		14.76	0
	M	10.558	10.491	4.6	94.1	1.56	0.12		M	10.558	10.499	4.1	94.8	1.36	0.172
log(DEBT)	U	4.4685	4.5611	−9.1		−1.93	0.053	log(DEBT)	U	4.4685	4.5611	−9.1		−1.93	0.053
	M	4.4659	4.4817	−1.6	82.9	−0.35	0.723		M	4.4659	4.4905	−2.4	73.5	−0.56	0.578
log(RDINVEST)	U	1.0908	0.89237	15.1		3.12	0.002	log(RDINVEST)	U	1.0908	0.89237	15.1		3.12	0.002
	M	1.1581	1.2414	−6.3	58	−1.53	0.126		M	1.1581	1.2526	−7.2	52.4	−1.74	0.082
log(Preliquidity)	U	8.4792	7.3646	66.7		12.95	0	log(Preliquidity)	U	8.4792	7.3646	66.7		12.95	0
	M	7.7896	7.7471	2.5	96.2	0.73	0.467		M	7.7896	7.7741	0.9	98.6	0.26	0.791
log(Preprofit)	U	8.0575	6.8373	71.3		13.98	0	log(Preprofit)	U	8.0575	6.8373	71.3		13.98	0
	M	7.3696	7.3153	3.2	95.5	0.92	0.359		M	7.3696	7.3312	2.2	96.9	0.65	0.518
log(Preasset)	U	10.277	9.0241	78.9		15.12	0	log(Preasset)	U	10.277	9.0241	78.9		15.12	0
	M	9.5449	9.4681	4.8	93.9	1.49	0.137		M	9.5449	9.4904	3.4	95.6	1.04	0.297
Age	U	26.921	23.57	28.1		5.48	0	Age	U	26.921	23.57	28.1		5.48	0
	M	24.675	24.478	1.6	94.1	0.42	0.678		M	24.675	24.48	1.6	94.2	0.41	0.682

Table 6
Test of balancing of covariates–Caliper matching with *n* = 5.

Caliper, bandwidth=0.05, <i>n</i> = 5								Caliper, bandwidth=0.01, <i>n</i> = 5							
		Mean				t-test				Mean				t-test	
Variable	Unmatched/Matched	Treated	Control	%bias	%reduct bias		<i>p</i> > <i>t</i>	Variable	Unmatched/Matched	Treated	Control	%bias	%reduct bias		<i>p</i> > <i>t</i>
log(EMP)	U	5.4702	4.5829	80.9		15.53	0	log(EMP)	U	5.4702	4.5829	80.9		15.53	0
	M	4.9467	4.9402	0.6	99.3	0.19	0.847		M	4.9467	4.9463	0	99.9	0.01	0.989
log(SALES)	U	11.273	10.127	77.9		14.76	0	log(SALES)	U	11.273	10.127	77.9		14.76	0
	M	10.558	10.505	3.7	95.3	1.24	0.216		M	10.558	10.51	3.3	95.8	1.11	0.267
log(DEBT)	U	4.4685	4.5611	−9.1		−1.93	0.053	log(DEBT)	U	4.4685	4.5611	−9.1		−1.93	0.053
	M	4.4659	4.4681	−0.2	97.6	−0.05	0.96		M	4.4659	4.4689	−0.3	96.8	−0.07	0.946
log(RDINVEST)	U	1.0908	0.89237	15.1		3.12	0.002	log(RDINVEST)	U	1.0908	0.89237	15.1		3.12	0.002
	M	1.1581	1.2419	−6.4	57.8	−1.53	0.125		M	1.1581	1.2409	−6.3	58.3	−1.52	0.129
log(Preliquidity)	U	8.4792	7.3646	66.7		12.95	0	log(Preliquidity)	U	8.4792	7.3646	66.7		12.95	0
	M	7.7896	7.7754	0.9	98.7	0.25	0.806		M	7.7896	7.7887	0.1	99.9	0.02	0.987
log(Preprofit)	U	8.0575	6.8373	71.3		13.98	0	log(Preprofit)	U	8.0575	6.8373	71.3		13.98	0
	M	7.3696	7.3402	1.7	97.6	0.5	0.62		M	7.3696	7.3536	0.9	98.7	0.27	0.788
log(Preasset)	U	10.277	9.0241	78.9		15.12	0	log(Preasset)	U	10.277	9.0241	78.9		15.12	0
	M	9.5449	9.507	2.4	97	0.73	0.464		M	9.5449	9.5136	2	97.5	0.6	0.547
Age	U	26.921	23.57	28.1		5.48	0	Age	U	26.921	23.57	28.1		5.48	0
	M	24.675	24.38	2.5	91.2	0.62	0.533		M	24.675	24.358	2.6	90.6	0.67	0.504

Table 7
Test of balancing of covariates-Caliper matching with $n = 1$.

Variable	Mean			t-test		
	Unmatched/Matched	Treated	Control	%bias	%reduct bias	p>t
log(EMP)	U	5,4702	4,5829	80.9	15.53	0
	M	4,9467	4,9712	-2.2	-0.71	0.48
log(SALES)	U	11,273	10,127	77.9	14.76	0
	M	10,558	10,528	2.1	0.7	0.486
log(DEBT)	U	4,4685	4,5611	-9.1	-1.93	0.053
	M	4,4659	4,4487	1.7	0.4	0.69
log(RDINVEST)	U	1,0908	0,89237	15.1	3.12	0.002
	M	1,1581	1,1991	-3.1	-0.76	0.449
log(Preliquidity)	U	8,4792	7,3646	66.7	12.95	0
	M	7,7896	7,7838	0.3	0.1	0.92
log(Preprofit)	U	8,0575	6,8373	71.3	13.98	0
	M	7,3696	7,3059	3.7	1.07	0.285
log(Preasset)	U	10,277	9,0241	78.9	15.12	0
	M	9,5449	9,5252	1.2	0.38	0.702
Age	U	26,921	23,57	28.1	5.48	0
	M	24,675	24,569	0.9	0.22	0.824

matching shows the best reduction in mean and median standardized difference. However, both nearest neighbor matching with calipers and Kernel matching results in a loss of treatment observations.

Tables 5, 6, and 7 show the quality of balancing in creating the treatment and control samples by using covariate imbalance testing, organized by matching method and weighting proposed by Rosenbaum and Rubin (1985). U represents the difference between each covariate in the control group and the treatment group before matching, and M represents the difference after matching. The method applies t-tests for equality of means in the treated and non-treated groups before and after matching. To be considered a good quality, the t-value after matching must be statistically not significant (Largoza, Favorada, Reinante, Tan & Thai, 2015). None of the selected covariates have a statistically significant t-value except internal R&D investment. Furthermore, this matching method satisfies the balancing property required by the algorithm presented by Becker and Ichino (2002). We can thus confirm that the characteristics of firms become similar after matching, which constitutes a positive environment for estimating the treatment effect.

Table 8 shows our main estimation results. The PSM approach assumes that the treated and untreated firms are sufficiently similar after matching based on the Propensity score by drawing with replacement of the set of control firms. As described above, we estimated the Kernel matching method and the Caliper matching method using bandwidths of 0.05 and 0.01, respectively. The bandwidths represent the difference that can be tolerated in the matching process. The lower the bandwidth, the more conservative the matching between treated and untreated firms. Furthermore, we check for robustness using both the cases $n = 1$ and $n = 5$.

We also match the data within industry and year for this estimation. This is to prevent inaccuracies that may arise from matching firms in different industry categories and years. Table 9 shows our results estimating the effect of R&D grant receipt on external financing receipt using treatment and control firms that are matched within the same industry category and year by drawing with replacement of the set of control firms. The PSM approach assumes that the treated and untreated firms are sufficiently similar after matching based on the Propensity score. As described above, we estimated the Kernel matching method and the Caliper matching method using bandwidths of 0.05 and 0.01, respectively. The bandwidths represent the difference that can be tolerated in the matching process. The lower the bandwidth, the more conservative the matching between treated and untreated firms.

All estimates remain significant except column (2) and (4) with smaller bandwidth with 0.01. This is due to the fact that as the bandwidth parameter gets smaller, more weight is given to closer propensity scores, thereby excluding some firms that do not fall within the strict caliper widths from the matching process. That is, as the caliper becomes limited due to weighting, the standard error increases, which in turn reduces the statistical significance of the estimation. However, 0.06 is the most widely used bandwidth in practice, and as shown in columns (5) and (6), statistical significance is recovered when we utilize the nearest neighbor matching method and designate $n = 1$.

Therefore, our results show that by matching individual samples and controls that are close in propensity scores and estimating the treatment effect partially helps alleviate the limitations faced when matching based on assigned weights and thereby allows for a more accurate matching.

In our study, R&D grants for the same industry-year match sample reduce the likelihood of receiving subsequent external financing by 22–32%, depending on the estimation method. As discussed above, this result comes from the differences in matching combinations, or the differences in the internal R&D investment covariates after matching, as shown in Table 5, 6 and 7.

Table 8
Estimation using PSM- Effects of R&D grant receipt on External Financing Receipt.

	(1)	(2)	(3)	(4)	(5)	(6)
Specification	Kernel, bandwidth 0.05	Kernel, bandwidth 0.01	Caliper, bandwidth 0.05	Caliper, bandwidth 0.01	Caliper, bandwidth 0.05, $n = 1$	Caliper, bandwidth 0.01, $n = 1$
Mean of control	0.1423	0.1423	0.1427	0.1427	0.1425	0.1425
External Financing Receipt Treatment effect	-0.0397*	-0.0397***	-0.0397**	-0.0412***	-0.0441**	-0.0458**
	(0.0208)	(0.0110)	(0.0182)	(0.0116)	(0.0186)	(0.0181)
Marginal effect	-0.278	-0.278	-0.278	-0.288	-0.309	-0.321

Standard errors in parentheses, Standard errors are bootstrapped with 100 replications.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Table 9
Estimation using PSM- Effects of R&D grant receipt on External Financing Receipt (Same Industry-Year Match Sample)***.

	(1)	(2)	(3)	(4)	(5)	(6)
Specification	Kernel, bandwidth 0.05	Kernel, bandwidth 0.01	Caliper, bandwidth 0.05	Caliper, bandwidth 0.01	Caliper, bandwidth 0.05, $n = 1$	Caliper, bandwidth 0.01, $n = 1$
Mean of control	0.1446	0.1446	0.1394	0.1394	0.1387	0.1387
External Financing Receipt Treatment effect	-0.0314**	-0.0314	-0.0347**	-0.0350	-0.0340*	-0.0344*
	(0.0127)	(0.0205)	(0.0175)	(0.0222)	(0.0174)	(0.0180)
Marginal effect	-0.217	-0.217	-0.248	-0.251	-0.245	-0.248

Standard errors in parentheses, Standard errors are bootstrapped with 100 replications.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

5. Conclusion and policy implication

R&D grants play an important role in society in that they address the problem of the underinvestment in innovation activities. However, such public support (including subsidy, award, or loan) should be designed to increase recipient's innovative capacity and to facilitate investment activities in the market. We have estimated the impact of a Korean R&D grant program on firm's external investment receipt with an internal data that has not been used in the existing literature by using the PSM method and by exploiting the idiosyncratic features of the Korean program.

The results of the empirical analysis suggest that a firm receiving the R&D grant has about 21% to 27% lower probability of receiving external financing than a firm without the R&D grant. This result can be regarded as an empirical validation of [Lach \(2002\)](#)'s claim that government subsidies lead recipient firms to substitute away from private investment even when they are capable of attracting such investment. It is also consistent with the claims of [Czarnitzki \(2006\)](#) and [Takalo and Tanayama \(2010\)](#) that grants themselves reduce the financial constraints of the firm and reduce the demand for external investment. Based on these results, we can derive some policy implications. First, targeted support based on the nature of the firm can be more effective than general R&D support. [Howell \(2017\)](#) asserts that the effect of support for younger and smaller firms is greater than for firms that are not. Therefore, it may be worth considering designing a targeted support policy that takes this analysis into consideration. Also, the system should be designed in such a way that it prevents the firms receiving the grant from becoming uncompetitive in the market.

In this study, we have conducted an empirical analysis of one aspect of the literature on the effect of governmental financial

support on corporate financial activities related to R&D. While previous studies were focused on small start-ups and on specific sectors and found that the government-sponsored support gave a positive signal to the market, our study is focused on companies of various industries and sizes.

Empirical analysis has been conducted thus far to show that innovation has positive effects on the firm's performance and technical progress including employment, productivity, and R&D expenditure in many regions such as Spain, US, Europe, and Canada. Also, studies have found that the linkage between the organizational culture and the type of innovation increases the effect. This study, using extensive data, focuses on determining the effect of government financial support on subsequent financing. While the empirical results may appear contradictory to cases in other regions, we suggest that there is an alleviating effect on the market failure to provide R&D funds to firms with R&D capabilities that are not supported by the market. Such public sector support will create an environment that can bring technological progress and growth suggested by the existing discussions to the firm.

In our empirical analysis, we found that government support should contribute to improving the practical capabilities of firms and create an environment for sustainable investment in the market. It is important to provide an opportunity for companies that receive support to actively participate in the private investment market, for example, by providing matching between government support and private funding as a condition of support. In addition, in the design of government-funded projects, consideration should be given to assessing whether the firm can be competitive in the market through government-sponsored projects. Moreover, measures to increase access to private capital based on such competitiveness after project completion should be considered.

Future studies may be conducted on the impact of firms receiving R&D assistance on their future financial market impacts on their investments from private sectors such as Venture Capital, as well as their impact on the size and total amount of the funds received. In particular, as this paper suggests, the extent to which firms receiving R&D support receive follow-up financial support, but if data on the frequency and size of follow-up finance are available, confirming the size of the support by case (that is, the number of cases is small, but large-scale external financial support) can also be an important research topic.

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