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Do the types of subsidies and firms' heterogeneity affect the effectiveness of public R&D subsidies? Evidence from China's Innofund programme

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This paper aims to fill the gap in the extensive literature on the results of interaction between public and private R&D expenditures. Two types of public R&D subsidies, the appropriations and loan interest, are investigated in the effect of public subsidies by applying for a unique micro data set of Chinese manufacturing firms combined with the Innovation Fund for Small and Medium Technology-based Firms (Innofund). The results are consistent with the prediction that loan interest subsidies based on more competitive selective system are more effective for the public R&D subsidies than the appropriations. Firms' heterogeneity, measured by state-owned enterprises (SOEs) and private-owned enterprises (POEs), is tested for the different impact of public subsidies on corporate R&D investment. The results show that the crowding-in effect is mainly driven by POEs, not by SOEs, which confirms the theoretical assumption by Aghion and Tirole that the agency problem play a dominant role in corporate R&D activities. An improved econometric method, combined propensity score matching with difference-in-differences estimation strategy, is applied for correcting the selection bias. Our results are robust to different matching techniques.

Keywords: public R&D subsidy, types of public subsidies, SOEs, propensity score matching, China

1. Introduction

One of the most exciting areas in economic science is where government and market interact. Public subsidies for R&D activities provide a platform for this interaction. On the one hand, in order to realize the social welfare, each government decides how to minimize the risk of public funding on private R&D projects. On the other hand, in order to maximize profits, firms reacting to the government R&D policy choose whether and how to apply public subsidies. Previous studies witnessed this interaction by analysing both public and private agents together.[1] However, there is a growing tendency of the existing literature to focus on the types of public subsidies and firms' heterogeneity when evaluating the effect of public subsidies (Dai and Cheng 2015a; Montmartin and Herrera 2015; Söderblom, Samuelsson, Wiklund, and Sandberg 2015).

The main concern of this paper is to assess the effectiveness of public subsidies in stimulating a firm's R&D spending, and subsequently analysing whether the effects are different depending

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on the types of public subsidies or the firms' heterogeneity. First, a detailed data set collected from the Innovation Fund for Small and Medium Technology-based Firms (Innofund) in China allows us to investigate both the effect of the appropriations and loan interest subsidies on corporate R&D investment. Second, a natural classification between state-owned (SOEs) and private-owned enterprises (POEs) in China provides us a good opportunity to test how the agency problem affects the effectiveness of public subsidies on corporate R&D investment. Third, a dynamic effect of public R&D subsidies on private R&D expenditure is presented by analysing whether a sustainable crowding-in effect of public R&D subsidies exists in Chinese manufacturing firms covering the period of 2001–2007.

A selection bias arises when R&D-intensive firms may well be more likely to apply for a subsidy or the government may just as well be more inclined to grant them a subsidy. Consequently, in recent research the econometric techniques have been introduced into this field of study to correct the selection problem (Aerts and Schmidt 2008; Czarnitzki and Lopes-Bento 2013). Following this line of econometric tendency, this study introduces the propensity score matching to correct the selection bias. Available for a firm-level panel data set of Chinese manufacturing firms, we refine the matching procedures by constructing a better counterfactual for the matched sample. An improved matching method enhances the matching precision by overcoming the mismatching often encountered in the cross-section data set in the previous studies.

This study makes several contributions to the existing literature. First, our study contributes to the literature on the interaction between public and private R&D activities. A large bulk of literature have confirmed the wealth of public R&D subsidies, though the mechanism through which types of subsidies stimulates private R&D investment is not clear. The most recent work shows that the subsidies awarded by a competitive basis are more effective than those assigned through an automatic procedure (Colombo, Grilli, and Murtinu 2011). Along this line of literature, this article is one of few papers that look at the effect of different types of R&D subsidies on corporate R&D investment from the firm-level perspective.

Second, we disentangle the subsided firms into SOE and POE and analyse the ownership impact on the relationship between public and private R&D investment. Most of the previous literature regards the awardees as homogeneous subjects. In contrast, we analyse the impact of the firms' heterogeneity on the interaction between public and private R&D investment. Our empirical investigation finds that the crowding-in effects of public subsidies is mainly driven by private-owned awardees not by SOEs. Following Aghion and Tirole (1994), this finding well responds to the critical view of 'heart darkness' by David and Hall (2000) and makes a further step towards opening the inside of the black box for the existent literature.

This study is structured as follows. Section 2 reviews the existing literature on the link between public R&D subsidies and firm-financed R&D. Section 3 introduces the background of the Innofund in China. Section 4 describes the data sets. Section 5 explains the method and introduces the model and variables. Section 6 discusses the empirical results with interpretations. Section 7 provides the concluding remarks and implications.

2. Literature review

2.1. *The types of public subsidies*

Previous studies indicate that public subsidies may encourage or discourage firms to invest more in innovative activities (David, Hall, and Toole 2000; Klette, Møen, and Griliches 2000; Zúñiga-Vicente, Alonso-Borrego, Forcadell, and Galán 2014). One of the reasons why the effects of the public subsidies on R&D investment are ambiguous is that most studies are lack of a clear understanding of the design of public programmes, which makes it difficult to accurately compare the impacts among different funding systems. As mentioned that given the importance of R&D

subsidies, the knowledge pertaining to comparing funding system is surprisingly small. However, there is tendency of a growing literature to distinguish the type of public subsidies when evaluating the effect of public subsidies.

The first tendency of the existing literature is to distinguish the type of public subsidies when evaluating the effect of public subsidies. A growing literature suggests that the additionality effect of public R&D subsidies dominates through a selective scheme based on the competitive mechanism (Colombo et al. 2011). These studies argue that government innovative supporting programme can be benefited from a competition-based granting scheme if competition among applicants is tough and the support programme is administered by a reputable governmental agency. As suggested by Lerner (1999), a competition-based selective scheme provides a certification of the quality of beneficiary government agency to uninformed third parties. This 'signal' alleviates hidden information problems, and makes it easier for government agency to obtain additional resources.

The competition story happens in various circumstances. Some researchers focus on European countries and compare national public grants with the grants provided by agencies of European Union (Garcia and Mohnen 2010; Czarnitzki and Lopes-Bento 2014; Huergo and Moreno 2014). For example, a recent study, Czarnitzki and Lopes-Bento (2014), compares between the effectiveness of the national and European supporting grants. They find that firms getting funding from both sources display the highest impact, while EU grants have a higher effect on innovation input when the firm receives funding from only one source. Others compare the impact of R&D funding among different public tools (e.g. Wu 2005; Carboni 2011). Romero-Jordán, Delgado-Rodríguez, Álvarez-Ayuso, and de Lucas-Santos (2014), for instance, examine the effectiveness between tax credits and public R&D grants to identify the potential determinants of firm R&D.

Furthermore, some recent studies have begun to focus on the allocation mechanism of R&D granting system to explain the reasons behind the competition story. Feldman and Kelley (2001) take an advantage of accessing to information from a specific survey of 1998 Advanced Technology Program applicants, including the ratings reviewers gave to the projects. They find that indicators of spillover potential such as the number of business and university linkages significantly affected the probability of winning an award. Cockburn, Kortum, and Stern (2002) focus on the patent examination process at the United States Patent and Trademark Office, in particular, on the role that some patent examiners' characteristics may have on patent litigation outcomes.

In this study, we identify the R&D grants by two different sources: the appropriations and loan interest subsidies. Compared to the appropriations granted by the Innofund, loan interest subsidies are providing interest requiring loans from commercial banks to expand the production scale of the innovation project. After going through the screening scheme of commercial banks, firms applied the loan interest subsidies are more likely innovative than others. Therefore, we argue that the loan interest subsidies may exhibit additional effect for supporting the innovative projects.

2.2. *The heterogeneity of subsided firms and the ownership structure*

In terms of firms' heterogeneity, the previous studies ranges from firm size, technological competence, to market competition (Lach 2002; González and Pazó 2008; Aschhoff 2009). For example, Lach (2002) finds a positive effect of public R&D subsidies for small firms but a negative effect for large firms. However, Aghion and Tirole (1994) suggest that the allocation of property right is an important factor for the public intervention with corporate R&D activities.

Aghion and Tirole (1994) are the pioneers for looking inside of the firms' innovative activities from the perspective of corporate governance. Aghion and Tirole (1994) develop a model that builds a relationship between the ownership structure and corporate R&D activities. Along the idea of Aghion and Tirole (1994), Rosenkranz and Schmitz (2003) prove that the optimal ownership structure may change over time due to a trade-off between inducing know-how disclosure and ensuring maximum effort. Empirically, Lerner and Wulf (2007) observe an emerging relationship between corporate compensation and innovative activities in the US companies, where more long-term incentives (such as stock options and restricted stock) are associated with more heavily cited patents. They also find that these incentives appear to be associated with more patent awards and patents of greater originality, while short-term incentives appear to be unrelated to measures of innovation.

A natural classification between SOEs and POEs in China leads us to test how the ownership structure affects the effectiveness of public subsidies on corporate R&D investment. The key issue is the agency problem because the agency cost of SOEs has been regarded higher than that of POEs. It is argued that public agencies have a systematic subsidy bias in favour of SOEs in China because of the political connections of SOEs with the government agencies (Dai and Cheng 2015a; Luo, Yang, Luo, and Liu 2016). Although the SOEs are more likely to be selected as the R&D awardees, the effectiveness of the public subsidies for the SOEs only exhibits an instantaneous neutrality (Boeing 2014). The 'picking the winner' strategy may be out of shape when selecting between the SOEs and the POEs.

According to the analysis of the relationship between the corporate ownership and R&D investment, this study has classified the firms' ownership types into SOEs and POEs in order to observe how the corporate ownership affects the efficiency of public R&D subsidies. Because the agency problem of SOEs is regarded more severe than that of POEs, we predict that the effect of the public R&D subsidies in SOEs would be less effective than that in private-owned firms.

3. Institutional background

3.1. *The evaluation of Chinese R&D subsidy programmes*

Chinese government launched a series of action plans which calls for a major upgrade of innovative capabilities in manufacturing industries in China.[2] As a consequence, Chinese government efforts were initiated to leverage the China's R&D expenditure from 0.90% of GDP in 2000 to 2.10% in 2015. This study is to evaluate the role of a largest Chinese governmental financial support project (Innofund) in the innovation of manufacturing firms in China. Though poor transparency of public funding system in China, there is a small growing literature on evaluating the effectiveness of the R&D subsidy programme (e.g. Zhu, Xu, and Lundin 2006; Kroll and Tagscherer 2009; Yang, Lee, and Lin 2012; Boeing 2014; Dai and Cheng 2015b). Boeing (2014) reviews the literature on the effective of public R&D programmes concerning to China. He restricts to the firm-level studies and finds only 10 papers, 7 in Chinese and 3 in English. Nine of 10 papers have rejected the crowding-out effect, an overwhelmingly effective result which has been challenged by the researchers (e.g. Hu and Jefferson 2009). Three of 10 papers, as Boeing (2014) points out, have employed appropriate econometric strategies to address selection bias.

In this study, we try to clarify under what circumstances the crowding-out effect has been rejected or not by employing an approved econometric strategy. Furthermore, evaluation of R&D subsidy programmes is essential for justifying their costs and to assist in the design of future public programmes of R&D subsidies. To our best knowledge there is no rigorous assessment on the Innofund in China.[3] This study is the first one to evaluate the effectiveness of this largest Chinese public R&D subsidy programme.

3.2. *The Innofund in China*

Innofund is a first and largest government fund especially for small technology-based firms (STFs, hereafter), which is set up upon the approval of the Chinese State Council in May 1999. However, the birth of the Innofund has its own reasons. The first and most important one is that the Innofund is part of the mission of revolutionizing the SOEs during the 1990s. For instance, there were 5.6 million workers laid off from the SOEs in 1999 (National Bureau of Statistics of China 1999). At the same time, there were over 370,000 small and medium manufacturing firms registered in China, accounting for 99% of the whole industry. It is a big challenge for the former Premier Zhu Rongji's government how to tackle the problem of unemployment. For the Fourth Plenum of the 15th Central Committee of the Communist Party of China (CCCPC), a priority is to invigorate small and medium SOEs. Therefore, Innofund has born at the right time. As cited the Innofund's objective from the website (www.innofund.gov.cn):

> (It) facilitates and encourages the innovation activities of STFs and the transformation of research achievements by ways of financing. Without aiming at profit-making for itself, the Innofund is to contribute to the national economic structure adjustment and the growth of economy, taking revenue increase and job creations as the reward.

In 2002, National People's Congress has passed the Law of the People's Republic of China on Promotion of Small and Medium-sized Enterprises, in which the Innofund was included. Just before the Innofund's establishment, Chinese government has legislated the Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements in order to protect the intellectual property rights.

The Innofund is administrated by the Ministry of Science & Technology and the Ministry of Finance of China. The Innofund has targeted small and medium firms registered in China with various ownership involving in the R&D activities to promote the development of new and high-tech industries and drive job creations and revenue increase as the reward. Applicants for the Innofund project must be required the following terms: (1) the fund should comply with the national industrial technology policies, bearing a relatively higher innovation level and stronger position in market competition. (2) The applicant should be a business corporation registered in China, with a complete and sound accounting system, and generally not more than 500 employees. Also the number of employees with college degrees is no less than 30% of all the employment. (3) The applicant should engage in research and development in high-tech products, no less than 3% of total annual revenue in R&D expenditures. The number of the employees engaged in R&D should be accounted for the proportion of 10% of all the employment.

3.3. *Funding by the Innofund*

The Innofund has mainly three forms of financing, which is appropriation, loan interest subsidy, and equity investment according to the specific characteristics of the project. Appropriation is mainly as the start-up capital to small firms founded by research personnel bearing their own scientific achievements; also providing partial subsidies to STFs for new product development and pilot-production. The appropriation amount to each project will generally not exceed one million Yuan RMB with a maximum of two million for key projects. Loan interest subsidy is providing interest for STFs requiring loans from commercial banks to expand the production scale of the innovation project. The total subsidy amount of an individual project is generally within one million Yuan RMB and two million for key projects. Equity investment is targeted to a few number of projects with a high level of technology starting point greater innovation capacity and market potential in emerging industries. Generally the investment from the Innofund will not exceed 20% of the registered capital of the investee company and will be redeemed within a time limit in accordance with law. Until the end of 2013, 46,282 projects were selected as the Innofund projects with a total funding of 26.83 billion Yuan RMB, covering about 37 provinces, cities or regions of the country.

4. Data

Our data come from three major sources. The first data set is the Chinese Manufacturing Firm Survey Database (CMFSD), which is compiled by China's National Bureau of Statistics (CNBS) covering the period 2001–2007. CMFSD includes almost all of Chinese manufacturing firms of the SOEs and non-SOEs with annual sales no less than 5 million RMB (equivalent to about $650,000). CMFSD is a major firm-level data source for researchers and policy-makers to investigate various economic and social topics in current China (e.g. Brandt, Van Biesebroeck, and Zhang 2014).

The second data set is the basic information on public R&D subsidy which is published on the website of the Innovation Fund for Technology Based Firms (http://www.Innofund.gov.cn). As discussed in previous section, one can find the information relevant to R&D subsidies, such as the name and address of firms, the project by nature, the dates approved by Innofund and the date finished the project, funding size, application number, funding sources in the annual reports of the Innofund.[4]

The National Patent Database is the third data set used in this paper which is provided by the State Intellectual Property Office (SIPO) of China. National Patent Database covers complete information for all patents filed in China, including the type of patent, the nature of the inventor, the owner of the patent, the filing and granting time, the category of the patent by industry, and others. Since the Patent Law of China first issued in 1984, the oldest patent information we can get is from 1985. This database has stored three types of patents, namely invention patents, utility model patents, and design patents. These three types of patents were used to construct our important control variable of patent stock. Finally, we identified the Innofund-backed firms in CMFSD by merging the above three datasets. Because the oldest information of firms' R&D expenditure we can get in CMFSD is from 2001, the final sample restricted from 2001 to 2007 with a total of 1954 firms that have won at least one Innofund project.

5. Method

5.1. *The correction of a potential selection bias*

A selection bias arises when R&D-intensive firms may well be more likely to apply for a subsidy or the government may just as well be more inclined to grant them a subsidy (Griliches 1986; David et al. 2000; Klette et al. 2000; Lach 2002). Consequently, in more recent studies the potential sample selection bias is taken into account through selection models, instrumental variable estimations, difference-in-differences (DID) estimations and matching techniques (Busom 2000; Lach 2002; Duguet 2003; Kaiser 2006; González and Pazó 2008). For example, Kaiser (2006) has employed a simultaneous probit model and Kernel matching for Denmark and did not find significant proof to reject the crowding-out hypothesis. While employing the conditional DID technique, Görg and Strobl (2007) and Aerts and Schmidt (2008) have found robust evidence to reject crowding-out effect and further verified the justification of government subsidies for private R&D activities.

To correct the selection bias, we follow the methodology used by Görg and Strobl (2007) and Aerts and Schmidt (2008) and introduce the matching procedures and the difference-in-differences estimation (PSM-DID).

As Caliendo and Kopeinig (2008) survey that the t-test is not the best way to evaluate the quality of matching, we follow their suggestions to conduct our propensity score matching programme. We refer to the original idea by Abadie and Imbens (2002, 2006) and implement the Z-statistics which are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors.[5]

5.2. *Model specifications*

To implement the propensity score matching estimation, we estimate the likelihood of receiving R&D subsidies (S) with a micro dataset of the Chinese manufacturing firms as follows:

$$\begin{aligned}\Pr(S=1|X=x_{j,t-1}) &= \beta_0+\beta_1\mathrm{INPATST}_{it-1}+\beta_2\mathrm{PRACPATST}_{it-1}+\beta_3\mathrm{DESPATST}_{it-1},\\ &+\beta_4\mathrm{SUBSIDY}_{it-1}+\beta_5\ \ln\ \mathrm{EMP}_{it-1}+\beta_6\ \ln\ \mathrm{CAP\_LAB}_{it-1}+\beta_7\mathrm{EXPORT}_{it-1},\\ &+\beta_8\ \ln\ A\mathrm{GE}_{it}+\sum \mathrm{Ownershi\,p}_{it}+\gamma_{\mathrm{industry}}+\gamma_{\mathrm{province}}+\gamma_{\mathrm{year}}+\varepsilon_{it},\end{aligned} \tag{1}$$

where X is a vector of the observable characteristics of the Chinese manufacturing firm sample during 2001–2007.[6] The receipt of R&D subsidies is denoted by a dummy variable (S) indicating whether the firm received the public subsidies from the Innofund during 2001–2007. As estimated from our sample, 1954 firms have received the Innofund subsidies between 2001 and 2007, which account for 56.8% of the innovative industrial firms.

As the patent data is provided by the SIPO of the P. R. China, we use all patent information in the SIPO database and generate the stock of patents for each firm i as the depreciated sum of all three kinds of patents at the SIPO from 2001 until 2007:

$$\begin{aligned}\mathrm{INPATST}_{i,t} &= (1-\delta)\mathrm{INPATST}_{i,t-}1+\mathrm{INPAT}_{i,t},\\ \mathrm{PRACPATST}_{i,t} &= (1-\delta)\mathrm{PRACPATST}_{i,t-}1+\mathrm{PRACPAT}_{i,t},\\ \mathrm{DESPATST}_{i,t} &= (1-\delta)\mathrm{DESPATST}_{i,t-}1+\mathrm{DESPAT}_{i,t,},\end{aligned} \tag{2}$$

where INPATST (PRACPATST, DESPATST) is the invention patent stock (utility patent stock, design patent stock) of firm i in period t and $t-1$, respectively, INPAT (PRACPAT, DESPAT) is the number of invention patent (utility patent, design patent) applications filed at the SIPO and δ is a constant depreciation rate of knowledge which is set to 0.15 as common in the literature (see Griliches 1986; Aerts and Schmidt 2008).

As the outcome variables, we consider the private R&D investment rather than the total R&D investment. We deduct the R&D subsidy from the total R&D investment in two different ways to obtain the private R&D investment, which focus on our research topic. The first method is that, for the qualified firms, we deduct year by year from the total R&D investment the amount of subsidies weighted by the annual R&D investment during the period of validity of the projects, and for the unqualified firms, only 70% of the subsidies is weightedly deducted from the total R&D investment annually. The second one, as a robustness check, is that we deduct the annually average amount of subsidies for the qualified firms and 70% of the subsidies for the unqualified firms. Therefore, R&D expenditure at the firm level during the Innofund project, RD (RMB thousands), is evaluated. And we also investigate the R&D intensity, RDINT (R&D expenditure/turnover) to mitigate the skewness of the RD variable. The log of RD and RDINT, respectively, ln RD and ln RDINT, are additionally evaluated as outcome variables.

The treatment variable is denoted by a dummy variable (S) indicating whether the firm received the public R&D subsidies from the Innofund during 2001–2007. As estimated from our sample, 1954 firms have received the Innofund subsidies between 2001 and 2007, which account for 56.8% of the innovative industrial firms. We distinguish between the different financing forms of subsidies. There are three forms of financing provided by the Innofund, which is appropriation, loan interest subsidy, and equity investment according to the specific characteristics of the project. As the companies in our sample have already established before receiving the subsidies, we only choose appropriation and loan interest subsidy to examine the crowding-out effect of two different financing forms.

Other important variables are defined as follows (see Appendix). A dummy variable indicating whether a firm received the other government subsidies including production subsidies in year $t-1$ (SUBSIDY) controls for the experience of dealing with the public authority. We ignore the intensity of the government subsidies in treatment and its effect. We argue that firms that have received other subsidies may be more likely to receive R&D subsidies because they presumably better access to information about governmental actions due to their previous applications. The firm size (ln EMP) defined as the log of the number of employees in year $t-1$ controls for the probability of gaining the R&D subsidies. On the one hand, large-sized firms may be more likely to received R&D subsidies because of their competitive advantage of size economy. On the other hand, in contrast to large firms, small firms often vulnerable to financial constraints may be more innovative in order to gain competitive advantage and development opportunities. So small firms may have more propensity to apply for the innovation subsidies than large ones. The log of ratio of capital to labour (ln Capital_labor) controls for the mode of production which is an important factor for the Innofund's decision-making to consider whether the applicants have the technological capability of innovation. The high level of the ratio of capital to labour indicates the high level of capital intensity and the technological capability. We also control for the degree of international competition by including a dummy variable (EXPORT) whether firms have exported or not. Firms that engage more heavily in foreign markets may be more innovative or have to meet the higher level of the requirements of the environmental protection or security etc., than others and, hence, more likely to apply for subsidies (Chen, Zhang, and Zheng 2016). The log of the firm's age (ln AGE) is included in the analysis as it is often claimed that older firms with long-term accreditation are likely to be subsided.

The CNBS data contains a continuous measure of ownership, which is based on the proportion of paid-in-capital contributed by six different types of investors, namely the state; collective investors; legal entities; foreign investors; investors from Hong Kong, Macao, and Taiwan; and individuals. We then classify our firms into state owned (SOE), private (PRIVATE), foreign (FOREIGN), collective (COLLETIVE), legal (LEGAL), Hong Kong, Macao, and Taiwan (HMT), based on the shares of paid-in-capital contributed by the six types of investors in each year. Specifically, we classify firms according to majority average ownership share. For instance, we define a firm as state owned in a given year if the share of its capital owned by the government state in that year is at least 50% (see Ayyagari, Demirgüç-Kunt, and Maksimovic 2010; Guariglia, Liu, and Song 2011, for a similar approach).

Finally, we include the three kinds of dummies in our analysis to control for the industry, time, and region fixed effect. The 2-digit industry dummies are allowed for differences between sectors in the economy. It is often found that R&D activities depend on industry characteristics. Firms operating in capital-intensive and highly concentrated sectors are more innovative and, hence, are more likely subsided. Moreover, Chinese government has launched some funding schemes, which are directly targeted at specific industries or groups of industries, like Strategic Emerging Industries programme. Year dummies capture macroeconomic shocks. We also include the

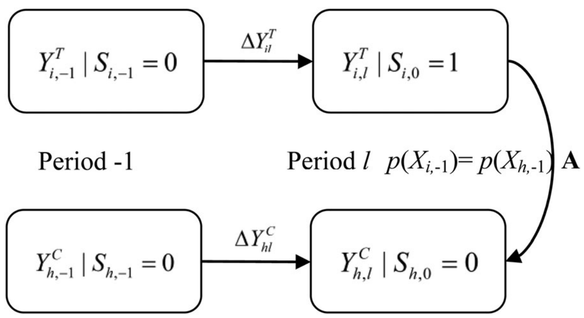

Figure 1: PSM-DID methodology.

province dummies to control for the difference of the development of regional economy and the importance of provinces in national economy.

6. Results and discussion

6.1. *Estimating propensity score and the balancing properties*

In order to apply the PSM-DID estimator, we first have to identify a good matching group from the sample of never-subsidized firms. In the PSM-DID estimation, only one matching procedure is required (matching A in Figure 1). The first step in matching A consists of estimating a probit or logit model on the receipt of subsidies. The estimation results presented in Table 1 show that the variables we considered in the model (1) are all important to receiving R&D subsidies, with one exception for the collective ownership type (COLLECTIVE). It is noteworthy that the patents

Table 1: Probit and logit estimation.

	Probit model		Logit model	
	Coefficient	Standard errors	Coefficient	Standard errors
INPATST_{-1}	0.7081***	0.1890	0.7245***	0.1907
PRACPATST_{-1}	0.6524***	0.1408	0.6325***	0.1204
DESPATST_{-1}	0.4531***	0.1124	0.4129***	0.1005
SUBSIDY_{-1}	0.2016***	0.0316	0.5300***	0.0879
$\ln \text{EMP}_{-1}$	0.0918***	0.0186	0.2628***	0.0534
$\ln \text{CAP\_LAB}_{-1}$	0.1460***	0.0180	0.4339***	0.0529
EXPORT_{-1}	0.1260***	0.0307	0.3488***	0.0852
ln AGE	−0.0049***	0.0013	−0.0135***	0.0038
COLLECTIVE	−0.0275	0.0695	−0.0612	0.1987
LEGAL	0.1830***	0.0603	0.5237***	0.1659
PRIVATE	0.2065***	0.0614	0.6041***	0.1704
HMT	−0.5520***	0.1168	−1.6758***	0.3700
FOREIGN	−0.6594***	0.1191	−2.0336***	0.3776
Industry dummies	Control		Control	
Province dummies	Control		Control	
Year dummies	Control		Control	
Constant	−3.6976***	0.2236	−8.5642***	0.6193
Log-likelihood	−4993.0149		−4992.1209	
Pseudo-R^2	0.1018		0.1019	
Number of observations	221,089		221,089	

Note: *** (**,*) indicate a significance level of 1% (5%, 10%).

Table 2. Descriptive statistics of matched sample.

Variables	Subsidized firms Mean	Control group firms Mean	Difference (%)	Results of t-tests on mean difference T	p
Covariates					
INPATST	4.3781	4.3833	1.2	0.27	(.433)
PRACPATST	6.9812	6.9986	1.4	0.19	(.602)
DESPATST	8.1248	8.1306	1.2	0.23	(.578)
SUBSIDY	0.2691	0.2778	−2.2	−0.36	(.718)
ln EMP	4.9167	4.9072	1.1	0.20	(.840)
ln CAP_LAB	3.8937	3.8732	2.2	0.41	(.679)
EXPORT	0.2937	0.2851	1.9	0.36	(.722)
ln AGE	16.3110	16.1360	1.7	0.31	(.759)
$P(X)$	0.0095	0.0092	3.5	0.50	(.618)
Outcome variables					
RD	743.34	232.53	31.1	5.40***	(.000)
RDINT	1.6227	0.4211	48.6	8.58***	(.000)
ln RD	3.5672	1.46	78.5	13.37***	(.000)
ln RDINT	0.5891	0.1803	70.3	12.18***	(.000)

Note: *** (**,*) indicate a significance level of 1% (5%, 10%).

owned by firms are a clear signal for Chinese government to allocate the R&D subsidies because of the positive relationship between three kinds of patent stock and the receipt of subsidies. The highly significant coefficient of getting government subsidies (including R&D subsidies) indicates that the experience of dealing with government is an important determinant of the probability to receive a subsidy in China.

In Table 1, we also find that firms with larger size, high level of capital intensity, and export sales have higher probability to receive subsidies; conversely, due to their lack of innovation, older firms are not likely to be subsidized. In terms of the type of firms' ownership, private firms are more likely to be subsidized, compared with the state, collective, and foreign firms, because the Innofund itself prefers the small and medium-sized private innovative firms. As a result, all of the variables in model (1) are included in the propensity score. In the second step, for each subsidized firm i a twin firm h is selected from the control group of never-subsidized companies with the hybrid nearest-neighbour matching technique (N-N matching, hereafter). The kernel matching technique is also used as a robustness check.

When we take the selected control group into account in the t-test present in Table 2, we observe no significant differences in all the control variables but highly significant in the outcome variables, R&D expenditure, R&D intensity, and their logarithm. The preliminary evidence in Table 2 indicates that the Innofund-backed firms are more R&D active; they spend more on R&D both in absolute terms and proportionally to the turnover. But this result should be considered with caution because the matching estimator only controls for observed heterogeneity between the treated and non-treated firms. Next, we will employ the DID method to control for the unobservable factors.

6.2. *Estimating the PSM-DID estimator*

6.2.1. *DID estimator for panel data*

In Table 2, the t-test after the matching shows that the selected control groups constitute a reliable match because all of the covariates for matching have no significant difference between the subsidized and the control group. After a reliable matched sample is selected from the control group, we next apply the DID estimator, which controls for unobserved determinants of receiving the R&D subsidies.

In Table 3, we present the final treatment effect estimations for the outcome variables both on the weighted deduction and average deduction of R&D subsidies. We map the dynamic pattern of the R&D subsidies by considering contemporary effect, as well as future effects. We refer to the impact at period $t = 0$ as the instantaneous impact, and the effect at periods later than period 0 as the future impact. Our baseline results are the propensity score matching procedures combined with difference-in-difference (PSM-DID) in panel data. We use the N-N matching with nearest neighbours as the main matching procedure. We also report the estimation results of kernel matching as a robustness check. Overall we find that public subsidies of R&D funded by the Innofund, both in absolute value and in logarithm, stimulate the private R&D investment between period 0 and period 3, but this phenomenon has vanished in the long run when the absolute value of R&D expenditure is rescaled by sales. Specifically, the crowding-in effects both in RD and ln RD go up from period 0 to period 3. The immediate impact on private R&D expenditure is 174,959 RMB and significant at 1% level, and rises up to 934,071 RMB at period 3. However, as the distribution of R&D expenditure in the economy is very skewed, the results should be interpreted with caution. When the R&D intensity, RDINT and ln RDINT both rescaled by sales, is evaluated, the additionality effect is only significantly positive at 5% level in period 0, and becomes insignificant in next three periods, with one exception for the log of R&D intensity (ln RDINT) in

Table 3: Average treatment effects on the treated firms: nearest-neighbour matching.

Variables		Scaled periods			
		0	1	2	3
Panel A: Weighted deduction					
RD	ATT	174.9585**	505.2234***	618.219***	934.0709***
		(2.35)	(3.89)	(4.06)	(4.89)
RDINT	ATT	0.2491**	0.1628	0.1478	0.3700
		(2.26)	(1.07)	(0.79)	(1.57)
ln RD	ATT	0.2837**	0.4082***	0.3800***	0.9084***
		(2.43)	(2.58)	(2.71)	(3.57)
ln RDINT	ATT	0.2330**	0.1561	0.1358	0.3541*
		(2.27)	(1.01)	(0.80)	(1.72)
Treat obs.		1954	1587	1284	1096
Control obs.		192,304	143,590	116,736	98,035
Panel B:Average deduction					
RD	ATT	166.0902**	523.5413***	599.0314***	929.0108***
		(2.55)	(3.77)	(3.81)	(4.88)
RDINT	ATT	0.1967*	0.2280	0.1343	0.3857
		(1.69)	(1.42)	(0.64)	(1.60)
ln RD	ATT	0.2561**	0.4031***	0.4154**	0.8831***
		(2.32)	(2.58)	(2.00)	(3.41)
ln RDINT	ATT	0.1861*	0.2197	0.1214	0.3691*
		(1.74)	(1.47)	(0.13)	(1.68)
Treat obs.		1954	1667	1384	1096
Control obs.		192,304	153,590	126,736	93,035

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%). The *Z*-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

period 3, indicating a lagged crowding-in effect. As a robustness analysis we redo the PSM-DID estimator based on the average deduction of R&D subsidies. The same dynamic pattern has been reported in Panel B, Table 3.

6.2.2. *The types of subsidies: appropriation vs. loan interest*

In this subsection, Table 4 shows the estimation results for the appropriation and loan-interest-subsidies receivers, respectively. For the appropriation group, we find that appropriation receivers only show greater innovation enhancement at the period of the receipt of R&D subsidies, no such significant crowding-in effect in the future periods. In contrast, for the loan-interest-subsidies group, we find clearly that loan-interest-subsidies receivers exhibit significantly larger innovation increase than the never-subsidized firms in periods 1–3, while no significant difference at the period of the receipt of R&D subsidies. Overall, we find a contemporary crowding-in effect of R&D subsidies on private R&D investment when firms have received the appropriation funded by the Innofund, whereas we find a sustainable crowding-in effect when firms have been subsidized in the form of low interest loan by the Innofund. The imbalance of the effectiveness of R&D subsidy between the forms of funding justified the proposition raised by prior literature (Huergo and Moreno 2014) that the inconsistent results in the area of R&D subsidies research are partly driven by the different objectives for different forms of funding system.

Table 4: Average treatment effects on the treated firms: appropriation vs. loan interest (nearest-neighbour matching).

Variables		Scaled periods			
		0	1	2	3
Panel A: Appropriation					
RD	ATT	141.9299**	181.1726	309.8136**	318.2347
		(2.51)	(1.28)	(2.03)	(1.18)
RDINT	ATT	0.1420*	−0.0509	−0.1673	−0.0587
		(1.92)	(−0.21)	(−0.49)	(−0.16)
ln RD	ATT	0.1753**	0.1217	0.2554	0.1013
		(2.18)	(1.10)	(0.76)	(0.27)
ln RDINT	ATT	0.1340*	−0.0431	−0.1566	−0.0499
		(1.94)	(−0.19)	(−0.50)	(−0.15)
Treat obs.		873	782	599	467
Control obs.		192,304	153,590	126,736	93,035
Panel B: Loan interest					
RD	ATT	45.2251	659.6401***	952.4513***	1200.6980***
		(0.45)	(4.17)	(3.63)	(4.18)
RDINT	ATT	0.1871	0.4080**	0.3331**	0.4199**
		(1.12)	(2.24)	(2.27)	(2.17)
ln RD	ATT	0.2489	0.9054***	0.6423**	1.1682***
		(1.49)	(4.12)	(2.40)	(3.34)
ln RDINT	ATT	0.1745	0.3884**	0.3031**	0.3986**
		(1.16)	(2.49)	(2.28)	(2.45)
Treat obs.		1081	885	785	629
Control obs.		192,304	153,590	126,736	93,035

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%).The Z-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

6.2.3. *State vs. private ownership*

Along the idea that allocation of property rights is an important factor for the public intervention of corporate R&D activities, it is necessary to test whether the estimated treatment effect are larger for private-owned firms than SOEs or vice versa. In order to test this hypothesis, we estimate the treatment effect in the subsample of both private firms and state-owned firms. Not surprisingly, it turns out in Table 5 that private-owned firms are more likely to reinvest in the R&D activities after subsidized by the Innofund in the next three periods while SOEs appear not inclined to spend more on R&D throughout the period 0 to period 3. Thus, the evidence in Table 5 shows that the hypothesis of crowding-out effect is rejected for the private-owned firms. The findings are consistent with our previous prediction and confirm the importance of corporate ownership when evaluating the public R&D subsidies.

6.2.4. *Matrix analysis*

The most serious concern in our study is the fact that the interaction effects between the type of Innofund subsidies and ownership of firms.[7] In Sections 6.2.2 and 6.2.3, we only compare the difference in the dependent variables between treatment and control groups by separating two different treatments. However, it is possible to consider the interaction effect of subsidy type and ownership, which can create a 2 × 2 matrix. In this case, we compare the average treatment effects of treated firms between the SOEs and the POEs when firms are supported by the appropriation and the loan interest subsidies respectively. The results are presented in Tables 6 and 7.

Table 5: Average treatment effects on the treated firms: private vs. SOEs (nearest-neighbour matching).

Variables		Scaled periods			
		0	1	2	3
Panel A: POEs					
RD	ATT	197.8700***	587.7731***	657.0461***	1150.3837***
		(2.79)	(3.10)	(3.70)	(4.28)
RDINT	ATT	0.1137	0.1072*	0.3156**	0.4243**
		(0.99)	(1.69)	(2.53)	(2.14)
ln RD	ATT	0.2791**	0.4509***	0.4123***	1.2033**
		(2.35)	(2.71)	(3.97)	(4.27)
ln RDINT	ATT	0.1080	0.1120*	0.3541**	0.4081**
		(1.01)	(1.78)	(2.47)	(2.15)
Treat obs.		1477	1285	1098	873
Control obs.		167,532	134,562	109,832	78,996
Panel B: SOEs					
RD	ATT	123.9491	134.5955	55.0124	105.9698
		(1.26)	(0.77)	(0.36)	(0.28)
RDINT	ATT	0.0780	−0.2243	−0.7231	0.0088
		(0.16)	(−0.40)	(−1.00)	(0.01)
ln RD	ATT	−0.1657	−0.1608	−0.2657	0.5803
		(−0.46)	(−0.40)	(−0.52)	(1.02)
ln RDINT	ATT	0.0995	−0.1756	−0.6363	0.0490
		(0.23)	(−0.35)	(−0.99)	(0.06)
Treat obs.		477	382	286	223
Control obs.		24,772	19,028	16,904	14,039

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%). The *Z*-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

Table 6: Matrix analysis on the type of subsidies: appropriation (nearest-neighbour matching).

			Appropriation			
Ownership			0	1	2	3
SOEs	RDINT	ATT	0.0573	−0.4563	−0.5421	−0.2347
			(0.34)	(−0.78)	(−1.23)	(−0.35)
	ln RDINT	ATT	0.0612	−0.4679	−0.5536	−0.2459
			(0.39)	(−0.85)	(−1.31)	(−0.40)
	Treat obs.		396	367	274	202
	Control obs.		17,653	14,328	11,795	9762
POEs	RDINT	ATT	0.0782	0.1034*	0.2348*	0.1583
			(0.32)	(1.80)	(1.79)	(1.54)
	ln RDINT	ATT	0.0903	0.1115*	0.2487*	0.1675
			(0.56)	(1.86)	(1.83)	(1.62)
	Treat obs.		582	415	328	265
	Control obs.		134,591	100,083	73,492	56,431

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%).The *Z*-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

Consistent with the results in previous sections, we find that the private-owned firms are more likely to engage in future R&D investment when obtaining both the appropriation and the loan interest grants while the SOEs are not. The results show that the ownership structure along the idea of Aghion and Tirole (1994) dominates the types of subsidies.

6.3. *Robustness check: Kernel matching*

As Smith and Todd (2005) note, kernel matching, a weighted matching procedure with the kernel weights can enhance the matching precision when the propensity score distribution is asymmetric between the treatment and the control group. Therefore, we use kernel matching as an alternative matching technique to test the robustness of our estimation results. We redo the PSM-DID estimator by introducing the kernel matching technique.

Table 7: Matrix analysis on the type of subsidies: loan interest (nearest-neighbour matching).

			Loan interest			
Ownership			0	1	2	3
SOEs	RDINT	ATT	0.1432	0.1891	0.0954	0.0438
			(1.36)	(0.76)	(0.26)	(0.57)
	ln RDINT	ATT	0.1560	0.1933	0.1007	0.0499
			(1.45)	(0.85)	(0.32)	(0.62)
	Treat obs.		190	138	125	118
	Control obs.		3765	3429	2987	2784
POEs	RDINT	ATT	0.1783	0.2348**	0.4127**	0.4762**
			(1.32)	(2.47)	(2.49)	(2.39)
	ln RDINT	ATT	0.1816	0.2436**	0.4238**	0.4831**
			(1.44)	(2.51)	(2.56)	(2.45)
	Treat obs.		891	747	660	511
	Control obs.		110,932	94,326	68,932	45,329

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%).The *Z*-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

Table 8 summarizes the estimation results for the Innofund-backed firms. We find that our main results remain robust to the kernel matching. We report the estimation results both on the average deduction and weighted deduction of R&D subsidies. For the weighted deduction method, the average treatment effect of subsidized firms in terms of the quantity of R&D expenditure and its logarithm are significantly positive throughout all of the periods, similar to our previous matching results in Table 3. As for the well-known skewness of the R&D expenditure, however, this significant effect disappears after the R&D expenditure is rescaled by sales turnover. Although the significance of the average effect of R&D subsidies has been regained at the period 0 and 3 by introducing its logarithm of R&D intensity, the results seem sensitive to the transformation of the outcome variables and appear an uncertain dynamic pattern similar to our previous results. For the average deduction method, a same pattern of the average treatment effect is presented in Table 3.[8] Overall, our results survived through different matching techniques.

6.4. *Multidimensional analysis*[9]

The multidimensionality of the problem generates results that differ in various dimensions and in signs, size of effects and their significance. In order to have a clear picture of the situation, we design a table where the result is classified by the common characteristics (dimensions) that we focus on in this paper. This will help to have a better conclusion regarding type of subsidy, firm heterogeneity, measure of outcome, and evaluation method and its effectiveness pattern of over time.

Table 8: Average treatment effects on the treated companies: kernel matching.

Variables		Scaled periods			
		0	1	2	3
Panel A: Weighted deduction					
RD	ATT	189.7779***	537.5306***	677.1040***	911.4229***
		(3.06)	(3.91)	(4.40)	(4.90)
RDINT	ATT	0.1781	0.2367	0.1411	0.3571
		(1.62)	(1.53)	(0.69)	(1.58)
ln RD	ATT	0.2999***	0.4979***	0.4913***	0.9894***
		(2.91)	(3.49)	(2.67)	(4.37)
ln RDINT	ATT	0.1683*	0.2277	0.1301	0.3458*
		(1.66)	(1.59)	(0.70)	(1.67)
Treat obs.		1954	1667	1384	1096
Control obs.		192,304	153,590	126,736	93,035
Panel B: Average deduction					
RD	ATT	201.9882***	543.5255***	677.3007***	916.3540***
		(3.24)	(3.95)	(4.39)	(4.92)
RDINT	ATT	0.2474**	0.2531	0.1348	0.3728
		(2.21)	(1.62)	(0.66)	(1.64)
ln RD	ATT	0.3582***	0.4753***	0.4314**	0.9641***
		(3.49)	(3.28)	(2.31)	(4.21)
ln RDINT	ATT	0.2334**	0.2432*	0.1239	0.3607*
		(2.27)	(1.68)	(0.66)	(1.71)
Treat obs.		1954	1667	1384	1096
Control obs.		192,304	153,590	126,736	93,035

Notes: *** (**,*) indicate a significance level of 1% (5%, 10%). The *Z*-statistics in parentheses are heteroscedastic consistent and adjusted by robust Abadie–Imbens standard errors (2002, 2006).

Table 9 presents a multidimensional analysis classified by the type of subsidy, firm heterogeneity, measure of outcome, and evaluation method and its effectiveness pattern of over time. We observe the additionality effect even when we change the measure of R&D input from the actual value to the intensity and their log transformation. However, the additionality effect is not persistent over time when we use the R&D scaled by the total assets (*Intensity*) and its log transformation.

Specifically, two types of subsidies have distinct effects on R&D investment. Appropriation has encouraged current private R&D investment, but no such effect in next future periods, while loan interests have persistent additionality effects. Private-owned firms exhibit a persistent stimulating effects of R&D spending while state-owned firms has no willing to invest R&D project after getting public grants.

7. Discussions and future directions

7.1. *Discussion on the measurement of subsidy*[10]

In this study, we use a dummy variable (yes, no) to measure the subsidy (S). We admit the data limitation that the use of dummy variables ignores the intensity in treatment and its effect. For example, a non-linear relationship between the subsidies and private R&D spending may exist when a continuous variable of subsidies has been used in our models. In other words, the additionality effect may be found until the amount of subsidies exceeds a critical point.

However, in order to implement the econometric method of PSM-DID, we should identify the sample firms into the treated sample firms and the matching ones by the dummy variable of

Table 9: Multidimensional analysis.

		Evaluation methods	Actual value	Log of actual value	Intensity	Log of intensity	Persistent over time
			RD	ln RD	RDINT	ln RDINT	
Total effects		PSM-DID	+				Yes
				+			Yes
					+		No
						+	No
Types of public subsidy	Appropriation	PSM-DID	+				No
				+			No
					+		No
						+	No
	Loan interest	PSM-DID	+				Yes
				+			Yes
					+		Yes
						+	Yes
Ownership	SOEs	PSM-DID	No effect				No
				No effect			No
					No effect		No
						No effect	No
	POEs	PSM-DID	+				Yes
				+			Yes
					+		Yes
						+	Yes

subsidies. To meet the requirements of this method, we have to sacrifice the rich information in a continuous variable of subsidies.

7.2. *Future directions*

Given the limitations of this study, future work needs to focus on following three points. One of the appealing research questions is the additionality effect on the output side. Recent studies have been conducted on output additionality, measured in terms of patents (e.g. Kim and Lee 2011). In addition to the patents, it would be interesting to look at other innovation indicators on the output side of the innovation process, such as the new product sales or processes (e.g. Guo, Guo, and Jiang 2016). Another research question deserve to answer is to distinguish the heterogeneous effect of R&D subsidy funded by the central government and the local government. The final point is the data limitation for the measurement of subsidies. A dummy variable of subsidies lost rich information contained in the R&D grants. An improved econometric method should be implemented in the future to capture the intensity and its treatment effect of continuous variables.

8. Conclusions

Overall, this study looks at inside of the black box of the public R&D subsidies to provide evidence that the types of public subsidies and firms' heterogeneity play an important role for the effectiveness of the public R&D subsidies. We empirically evaluated the effectiveness of public R&D subsidies on private R&D investment in China, using a panel data merged the largest Chinese governmental support programme (Innofund) with the CMFSD and National Patent Database. To tackle the problem of selection bias, we employed the PSM-DID method controlling for observed heterogeneity. In an analysis of dynamic pattern of R&D subsidies, our baseline results showed that the public funding from the Innofund only had a contemporary crowding-in effect, but no any long-term effect. However, further investigation showed that sustained crowding-in effects exist only if the sample firms were owned by private persons, or were funded by loan interest subsidies. More importantly, this detailed analysis tells us that the effectiveness of public R&D subsidies in China largely depends on the micro- and macro-economic environment that firms are operating in.

As David and Hall (2000) point out that the darkest area in the literature is where the public and private R&D investment interact, this study tries to lend some light on a long-standing debate over how effectively the R&D subsidies can stimulate private R&D investment. This study suggests that the allocation system of public subsidies based on a competitive basis such as the loan interest is more effective than those assigned through an automatic procedure, which is consistent with Colombo et al. (2011). As suggested by Lerner (1999), the loan interest as a competitive scheme serves as a certification of the quality of innovative projects to filter poor-quality R&D programmes. According to this findings, the design of government programmes, that is, the structure of the subsidy, seem critically important. Government should keep in mind when designing the structure of subsidies in order to identify the 'good' projects. The evidence of the effectiveness of credit guarantees from Korean, where the Korean government has invested a significant amount of resources through credit guarantee funds for promoting SMEs' survival and R&D investment, has confirmed our competitive story (Heshmati 2015).

This study also implies that government should consider the operating efficiency of the subsided firms when selecting the awardees of the R&D subsidy programmes. Fortunately, according to our findings, the policy-makers of the Innofund could identify the most effective applicants, the private-owned firms, by the ownership types of firms, which is consistent with the recent studies (e.g. Yu and Wu 2014). This study further implies that the private-owned firms are still the most active part in the innovative economy which the Chinese government should pay more attention on. It becomes a great challenge for the Chinese government how to promote the large part of the state-owned economy to innovate. For other Asian countries, public R&D granting agencies should carefully design their allocating schemes when the awardees' heterogeneity matters. For example, the innovative behaviours of the Chaebol firms and SMEs in Korean may be different (Lee and Rhee 2008). The findings of this study aim to lend lights on the situations which the firms' heterogeneity are important for the effectiveness of public R&D granting.

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Notes

1. The pioneer of opening the black box of innovation can be traced to Aghion and Tirole (1994), which first provides theoretical foundations on the organization of the R&D activity in an incomplete contract framework.
2. In 2006, the former President Hu Jingtao has aspired to make China an 'innovative nation' and constituted the Strategy of Innovation-driven Development as a key state policy. In 2013, the new government led by President Xi Jinping published a guide for enhancing enterprises innovative capabilities at a national level and proclaimed innovation as one of the key pillars in its policy to achieve economic transformation.
3. Our work is relevant to, but different from Guo et al. (2016), since we focus on the effectiveness of input of Innofund's subsidies, different from Guo et al. (2016), aiming to the output of Innofund's subsidies.
4. Guo et al. (2016) has used the public R&D subsidies from the Innofund to examine the output effect of subsidies in China, which is different from our work since we focus on the effectiveness of input of Innofund's subsidies, whereas Guo et al. (2016) aims to the output of Innofund's subsidies.
5. Thank for the reviewer to clarify this point.
6. To control the characteristics of firms previous to receiving the R&D subsidy, we take a lag of all explanatory variables at the period of $t-1$.
7. Thank for the reviewer's comments.
8. For brevity, we omit the tables on the average deduction method.
9. Thank for the insightful comments from the anonymous reviewers.
10. Thank for the comments from the anonymous reviewers.

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Appendix. Variable definition

Variables	Definition
RD	The absolute value of R&D expenditure in year t (RMB thousands)
RDINT	R&D expenditure/turnover
ln RD	The natural logarithm of the absolute value of R&D expenditure in year t
ln RDINT	The natural logarithm of RDINT
INPATST	The number of invention patents stock of firm i in period t and $t-1$
PRACPATST	The number of productive patents stock of firm i in period t and $t-1$
DESPATST	The number of designed patents stock of firm i in period t and $t-1$
SUBSIDY	One if a firm received the other government subsidies including production subsidies in year $t-1$
ln EMP	The log of the number of employees in year $t-1$
ln CAP_LAB	The log of ratio of capital to labour
EXPORT	One if firms have exported otherwise zero
ln AGE	The natural logarithm of the firm's age
COLLECTIVE	One if the share of its capital owned by the collective firms in that year is at least 50% otherwise zero
LEGAL	One if the share of its capital owned by the legal person in that year is at least 50% otherwise zero
PRIVATE	One if the share of its capital owned by the private person in that year is at least 50% otherwise zero
HMT	One if the share of its capital owned by the person or firm registered in Hong Kong, Marco, and Taiwan in that year is at least 50% otherwise zero
FOREIGN	One if the share of its capital owned by the foreign individuals or firms in that year is at least 50% otherwise zero
CASHFLOW	The ratio of the sum of net profit and depreciation over total assets