Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

The signal effect of Government R&D Subsidies in China: Do ownership matter?

Aihua Wu

School of business, Ludong University, China

ARTICLE INFO

Article history:
Received 25 April 2016
Received in revised form 11 August 2016
Accepted 15 August 2016
Available online xxxx

JEL classification:
H23
H25
M21
P26
D21

Keywords:
R&D subsidies
Ownership
R&D investment
Signal effect
Certification effect

ABSTRACT

R&D subsidies as a policy instrument are used to reduce market failure, apart from its input and output additionality, the notion of behavioural additionality has caused increasingly interest. We focus on the signal/certification effect of behavioural additionality, which means that government grants may serve as a signal for private investors. The signal effect is a certification enhancing a firm's access to external finance. The objective is to examine the impact of different ownership nature to the signal/certification effect. We use data on Chinese listed corporations from 2009 to 2013. The results show that receiving R&D subsidies increases the likelihood that firms will raise external finance, and the state-owned enterprises can receive more subsidies than private enterprises. However, the signal effect of R&D grants is stronger in private enterprises than that in state-owned enterprises of China, indicating that the ownership nature does matter in the R&D subsidies certification effect. This paper enriches current literature of government R&D subsidies by providing empirical evidences in Chinese mixed market.

1. Introduction

Government subsidies for R&D are intended to alleviate market failures in R&D activities, which may be caused by spillovers of ideas to competitors or a low appropriability rate (Kleer, 2010). In recent years Chinese government has paid more and more attention to scientific and technological activities and the expenditures on them continue to increase. According to "China Science and Technology Statistics Yearbook 2013", intramural expenditure on R&D has increased from 154.0 to 1331.2 billion yuan (RMB) from 2003 to 2014, of which the government funds increased from 46.1 to 319.5 billion yuan. Why does the government increase R&D subsidy significantly? Can the subsidy policy affect the R&D activities of enterprises?

Generally speaking, the R&D subsidies from government have positive effects to innovative enterprises' activities, for example, alleviating their tendency to underinvestment in R&D activities (Meuleman and Maeseneire, 2012). However, another effect of R&D subsidies, the signal effect or certification effect has not attracted enough attention. The signal/certification effect means that the government can certify that the granted enterprises are valuable to investment to private financiers by subsidies, thus government grants may serve as a signal for nice investments to private investors (Meuleman and Maeseneire, 2012). In this paper, we examine this effect empirically, that is, whether government subsidies to R&D increase external R&D investments, improving enterprises' access to external finance in general in Chinese context, and whether the effect is different in different ownership structure, such as state-owned and private enterprises.

From the perspective of additionality, most of the literatures on R&D subsidies are primarily concerned with whether a government grant has positive effects on input (e.g., increase in R&D efforts) and/or output additionality (e.g., increase in growth/employment/number of patents). Our analysis evaluates another additionality effect, i.e. behavioural additionality, it means that obtaining a grant may induce changes in the enterprise's behavior. From a systemic view on innovation processes, innovations are created within a complex web of interactions between different actors of the innovation system (Fischer, 2001). So more general, the behavioural additionality may also change the behavior of other actors towards the enterprises, for example, it may change the behavior of banks towards the enterprise (Meuleman and Maeseneire, 2012). The signal/certification effect, as a kind of behavioural additionality, means that government officials may certify firms worth investing by granting subsidies. Given the uncertainty, receiving a subsidy might act as an observable indicator of the unobservable applicant's quality (Hauessler et al., 2012). Consequently, R&D subsidies weaken the information asymmetries, beneficial for external financing.

As for ownership, actually, public firms are present in several industries such as banking and insurance, gasoline distribution, radio,

E-mail address: hiwuaihua@163.com.

http://dx.doi.org/10.1016/j.techfore.2016.08.033
0040-1625/

television, automobile and steel, health-care and energy (Anderson et al., 1997). And there are a great many public firms in China, because of the special market situation of Chinese transition economy, state-owned and private enterprises have coexisted in the market for a long time, which is also known as the mixed market. Chinese economic transition from centralized to open makes it a particularly interesting context to examine the links between ownership and government R&D subsidies effects. State-owned enterprises (SOEs) are directly controlled by the government, as the controlling owner of shares, will the government grand more R&D subsidies to SOEs than to private enterprises? Moreover, are there some differences about the signal/certification effect of government R&D subsidies between the state-owned and private enterprises?

We address those questions based on the case of Chinese listed corporations. Xu and Xu (2013) consider that the government R&D subsidy is even more important for firms in emerging economies, such as China. And the study of R&D activities in mixed markets is becoming increasingly popular from a theoretical perspective (e.g. Poyago-Theotoky, 1998; Ishibashi and Matsumura, 2006; Cato, 2011). However, most of the literatures about the roles of R&D subsidies in mixed markets are based on game model, for example, Gil-Moltó et al. (2011) propose a model to examine the use of subsidies to R&D in a mixed and a private duopoly market, and they take social welfare maximization as the goal of SOEs, which is not accord with the reality of Chinese SOEs. In fact, Chinese SOEs are not to maximize the welfare of society as the goal, but pursuit more objects. It is well known that the chairmen of the SOEs are appointed by Chinese government so they also may seek the politicians' personal goals, such as solving the problem of employment to win the election etc. Above all, SOEs are researched in the context of China as a peculiarity of the state-managed economy (e.g., Yusuf et al., 2006; Guan et al., 2009; Chan and Daim, 2011). In addition, the differences between SOEs and private enterprises is not only reflected in different objective functions, these two kinds of enterprises are different in investment behaviors, R&D efficiency, communication mode and frequency with the government, these differences can also influence R&D subsidy effect to themselves. Thus it is valuable to test the R&D subsidies effects in Chinese mixed market, which can extend the R&D subsidy research scope.

Even though much attention has been given to the input and output additionality, the effect of R&D grants on firms' ability to raise external financing has attracted virtually no scrutiny, especially to different ownership nature. In this paper, we examine whether obtaining an R&D grant facilitates state-owned and private enterprises' subsequent access to external financing as a consequence of the signal/certification effect. Our work also adds to the subsidy policy literature since we examine the impact of receiving an R&D grant on external investment of both state-owned and private enterprises.

Especially, to the best of our knowledge, no previous study has investigated the effect of obtaining R&D subsidies on the enterprises' access to debt financing. Esty and Megginson (2003) argue that debt markets have supplied a much larger proportion of external finance than equity markets. Similarly, Qian and Strahan (2007) also point out that banks are the main external funding providers in most countries. China also has a bank-centered capital market with many state-owned and private enterprises in transition economy, so exploring whether the subsidies can induce more investments from banks or not, comparing the induced investment amount to state-owned and private enterprises in Chinese context, can deliver important insights into impacts of public R&D support in Chinese SOEs and private firms, also enlightening other transition economies.

The remainder of the paper is structured as follows. In the next section, a brief literature review is provided and the research hypotheses are developed. A description of the method and sample used are then presented. Next, the empirical results are described and the impact of the R&D subsidy is analyzed. Last, the findings and limitations are discussed and some interesting topics for further research are pointed out.

2. Literature review and hypotheses development

After a long time attention to the relationship between government R&D subsidies and enterprise R&D activities, gradually in recent years scholars have focused on another role of R&D subsidies, which serve as a signal for good investments to outside investors, and it is proved that the government R&D subsidy can provide the choice standards for R&D projects to external investors, promoting enterprises with subsidies to attract more external investments. Narayanan et al. (2000) argue that actions related to governmental agencies, like approving new products, granting patents or awarding subsidies, may serve as an information signal to other investors. Takalo and Tanayama (2010) provide a theoretical model in which public R&D subsidies may yield a positive signal to market-based financiers. Empirically, based on 1435 small business innovation research (SBIR) awardees from 1983 to 1985, Lerner (1999) finds that R&D grants provide a positive signal about enterprise quality and technological merits of the firms' projects, thereby alleviating capital market imperfections that facilitates attracting venture capital. He attributes capital market imperfections, specifically the difficulty to raise capital for uncertain R&D projects due to information asymmetries as a source of difference in performance.

The asymmetric information between firms and investors is usually considered as an important reason for preventing enterprise to attract external investment, and R&D intensive companies are particularly vulnerable to distress because the R&D activities involve many technical details and secrets. The activities need participants not only have professional knowledge, but full participation in the process of research, at this circumstances the R&D information is mainly predominated by the enterprises. Instead, due to the limited professional knowledge, outside investors are difficult to evaluate the advantages and disadvantages as well as the expected return of R&D projects, so it is difficult for them to support the R&D projects financially. Hall (2002) reviews the possible underinvestment in R&D caused by capital market imperfections. From the perspective of accounting, she finds that there is no capitalized value for R&D in a firm's balance sheet. Asymmetric information between borrowers and lenders may then cause potential lenders to be reluctant to fund R&D due to its inherent risk, even if the borrower promised high expected returns.

On the other side, as the R&D activities have positive externalities, even if enterprises want to attract external investment, but for the purpose of self-protection, enterprises will not disclose a large number of R&D information publicly, which further aggravates the information asymmetry between themselves and investors. In addition, the R&D projects often have high risks, so investors keep cautious on R&D investment. The government can use the “visible hand” to intervene when facing market failure, playing an important role of macroeconomic regulation. Among them, government R&D subsidies can play an important role in certifying firms' quality and technological merits of the R&D projects, thus the effect of R&D subsidy is not only limited to directly reduce the cost of R&D, but as a positive signal for good prospects of the enterprises gained subsidies to outside investors. The National Governors Association (NGA) also claims that “an SBIR award provides a signal to angel investors that these technologies hold promise and an opportunity to leverage their investments with another source of early-stage funding” (NGA, 2008, p.7). Specially, the signal effect works through the following two ways.

Firstly, in order to make the subsidies have positive effects to the projects, governments will be rigorous in the process of evaluating R&D projects. With a perfect R&D project identification standard system, the evaluation results from the governments can be transferred to outside investors through the form of R&D subsidies. Governments might be better motivated to screen projects than market-based financiers because of different objective functions and potential free rider problems among private financiers (Meuleman and Maeseneire, 2012). The governments often set up special organizations and invite lots of experts to choose right R&D projects, and a large number of

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experts in the same field also can overcome the information asymmetry. In addition, the governments have an information advantage over private financiers because they receive many subsidy applications from enterprises, making an accurate overview of various fields possible. Lerner (2002) argues that it is reasonable that government can overcome information problems whereas private investors cannot. For example, experts may have considerable insight in which companies and technologies are most promising, while the traditional financial statement analysis undertaken by bankers would be of limited value. Thus, again, when projects are difficult to evaluate, as in high technology industries or new markets, the R&D grant is more important to secure private funding (Kleer, 2010).

Secondly, as government does not compete directly with enterprises, enterprises are more willing to provide relevant R&D information to government than to outside investors. As argued by Bhattacharya and Ritter (1983) and Ueda (2004), the threat of expropriation may limit screening activities. If enterprises have to reveal valuable private information about the R&D projects to external investors in order to get funds, they are in dangerous situations that the external financiers may steal the ideas and information of the project. However, the government is not directly compete with enterprises, which does not involve the information security problems. On the other side, enterprises must provide a large number of first-hand information about R&D projects to apply R&D subsidy funds. R&D information from enterprises not only can help them get the subsidy from government, can also avoid R&D project information leakage in the process of social financing to get private capital, thus reducing the information asymmetry.

In sum, the selection results of R&D projects from government are believed to be more accurate and unprejudiced, which can provide valuable investment signals for outside investors. What's more, it is also believed that the enterprises with government R&D subsidies have advantage and potential in R&D prospects and management ability, therefore in the external investors' views, R&D subsidy can play a role of wind vane, providing the signal quality of R&D projects. Government subsidies have the role of signaling the market that certain types of products are currently encouraged to develop (Xu et al., 2014). Some empirical studies have confirmed the signal effect of R&D subsidies. For example, in an interview study of firms, Feldman and Kelley (2006) find that receipt of a government R&D subsidy increased the company's funding from other sources. They argue that when the agency's assessment is linked to the commercialization potential, private investors may consider the award winning project as more valuable than other high risk research projects. A more recent empirical analysis of Meuleman and Maeseneire (2012) also confirms the conclusion, they find a positive certification effect of obtaining an R&D grant. Thus, we propose the following hypothesis:

Hypothesis 1. The government R&D subsidies have a role of signal/certification effect, namely the government R&D subsidies can induce external investments.

A large proportion of national industrial output is still produced by state-run companies in many developed and developing economies (OECD, 2005). As Tõnurist (2015) argues that SOEs' role in science and technology (S&T) policies is still significant – in combination with internal R&D expenditures, collaboration with research institutes, procurement for innovation, etc. – even though it has mostly remained unobserved. However, most of the current SOEs research is focused on the topics of privatization and efficiency (e.g., World Bank, 1995; Netter and Megginson, 2001; Omran, 2004). Those literatures usually present a negative argument with regard to the role of SOEs in policy making (Tõnurist, 2015). Thus the literatures of traditional governance and management tend to ignore innovation as a goal or to minimize its role in SOEs. Christiansen (2013) argues that SOEs have had many different goals and also varied reasons for being created in developed and developing economics.

In the US, SOEs are seen as an extension of the government and its agencies rather than businesses that serve national objectives (Tõnurist, 2015). Sometimes they play a role similar to venture capital funds (Weiss, 2014). However in China, the aim of SOEs is to maintain control over strategic industries, build them up and make direct investment (Chan and Rosenbloom, 2009; Kroll and Liefner, 2008). In addition, MacAvoy et al. (1989) provide a list of SOEs functions including resource preservation (maintenance of vital industry), simply rent collection from resource-based industry, value promotion (interest in non-commercial values) and hording (problems with allocating property rights to national resources). Thus, SOEs undertake some aims of government, which forms the policy burden to the enterprises (Lin et al., 1998).

To help SOEs to realize the aims, government has the motive to support them. What's more, SOEs possess the information advantage for government subsidies by the politics communication. SOEs may exaggerate the R&D input to obtain government subsidies by using the information advantage, which may induce more R&D subsidies. As the allocation of power concerned, Chinese government has experienced a process from centralization to decentralization, at this context, local governments have gained more financial autonomy and economic management authority, to develop local economy, local governments also have a motivation of gaining more resources from central government (Cao et al., 1999; Poncet, 2005). As the SOEs have more advantages than the private enterprises in promoting regional economic development, increasing employment and promoting technological progress, they attract more R&D subsidies from local governments.

In addition, as a kind of scarce resources, government R&D subsidies are pursued by many enterprises, easily causing corruption. There are some social network relationships more or less between enterprises and government, so in the application of R&D subsidies, enterprises often try to use their own social network relationships to provide convenience for their access to R&D subsidy resources since business in China is heavily rooted in social relationships and personal connections (i.e., *guanxi*) (Su et al., 2007; Shu et al., 2012). Although SOEs have their own boards of directors, their relationships with government regulators are closer than private enterprises, so they have stronger government connections than private enterprises. SOEs can also acquire and maintain government connections through personnel arrangements and relationships. Especially, chief executive officers (CEOs) of SOEs are appointed by governments, showing the close relationships between SOEs and governments (Cull et al., 2014). Therefore the relationships between SOEs and Chinese government are closer than that between private enterprises and government.

There are more interactions and contact between SOEs and the government, especially in some of the major industries important to livelihood, such as water and electricity industries, SOEs are still used as a tool to carry out the government's macro-control policy, so the interactions between government and SOEs are very frequent. From the perspective of principal-agent theory, there are many different levels of principals in SOEs, and the final principals of SOEs are dispersed widely, which induces that government officials begin to conspire with the managers of enterprises in order to complete the reciprocal exchange between them. All of those lead to the unfair market competition. Private enterprises can also try to establish a good relationship with the government, but compared with SOEs, they must expense higher cost to maintain the government relationship, therefore, we propose the following hypothesis:

Hypothesis 2. The SOEs can get more government R&D subsidies than private enterprises.

The discussions in Hypothesis 1 simply assume enterprises as homogeneous, without considering the differences in the nature of the enterprise ownership. In fact, state-owned and private enterprises have coexisted for a long time in Chinese market, as mentioned above, there

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are many differences between the two kinds of enterprises, such as the resources, objectives and financial constraints, leading to difference effects of R&D subsidies.

The signal/certification effect builds on the assumption that the government's assessments are independent and technically sophisticated, which has received support in the previous literature (e.g., Lerner, 1999, 2002; Feldman and Kelley, 2006). However, this certification effect is reduced in Chinese SOEs because the government's unfair assessments. To obtain R&D subsidy, SOEs may provide some false R&D information. Due to the close relationships between SOEs and government, the government officials not only pay no heed to the false information, but even help SOEs to conceal the facts in some cases. In the R&D project assessment, the government can choose and construct standards advantageous to SOEs, making their projects seem to have a better anticipation than that of private enterprises. Finally, even if the R&D projects are still unable to obtain a high evaluation score, sometimes the government officials can even tilt the R&D subsidy policy to the SOEs in the name of beneficial to livelihood.

Different from SOEs, government subsidies to private enterprises will be more dependent on the information collection and the R&D projects themselves rather than political relations. At the same time, private enterprises pay more attention to the results of R&D activities, once the R&D activities fail, it is possible to lose the trust of the public and the opportunities of receiving subsidies in the future. The close relationships between SOEs and government are well-known in China, of course the outside investors also know that SOEs can obtain government subsidies more easily than private enterprises. Therefore, rational external investors inevitably take these factors into account to invest in R&D projects, which will weaken the signal/certification effect of R&D subsidy in SOEs. Based on the above discussion, we propose the following hypothesis:

Hypothesis 3. The signal/certification effect of government R&D subsidies in SOEs is weaker than that in private enterprises. Namely, the same R&D subsidies promote more external investment in private enterprises than that in SOEs.

3. Research design

3.1. Sample

Taking Chinese listed companies as sample, this paper selects the companies at least 5 years continuous disclosure of R&D intensity data and the data of government R&D subsidies from 2009 to 2013. Because the influence of R&D subsidies on R&D investment lags behind, all government R&D subsidies lagged one period of enterprises' R&D investment. In the process of data selection, eliminating the enterprises without R&D investment, government subsidies, special treatment or particular transfer enterprises, the final selection of sample size is 485.

3.2. Variables

The measure for government R&D subsidies intensity is standardized by government's R&D subsidies divided by total assets, i.e. the subsidy amount related technological innovation from the item of non-operating income in the consolidated income statement divided by total assets. Compared with the stock market, the external debt market can give enterprises a greater proportion of financing, having become a major source of external financing, so the choice of financial loans as external investment index is reasonable. Two indexes are usually used to measure the innovation performance, including new product sales and the number of invention patents. New product sales indicate the effect of public R&D subsidies on firm's innovation output evaluated by the market, and the number of invention patents measures the inventive output of a firm at an intermediate stage of the R&D process, i.e., when the invention is not yet commercialized.

Further, a number of control variables are used in this study. Empirical evidence shows a positive relationship between firm size and the likelihood of engaging in R&D activities. Hence, we expect a positive relationship between firm size and the probability of R&D activities. Firm size is measured by the value of assets. On the one hand, the activities of R&D and innovation are dynamic processes where temporal persistence is relevant, so older firms have more probability and opportunities to engage in R&D activities. On the other hand, younger firms are more likely to suffer from financial constraints, so their desire for R&D subsidies is higher than older firms. In addition, competition can promote the enterprises to carry out innovation activities by constructing model to discover the enterprise innovation behavior under different market structure (Arrow, 1962). Thus, there is a big difference between different ownerships. It is no doubt that human capital is a key factor affecting R&D activities. R&D investments are subject to financial barriers, and the profit getting from operation is one of the important sources of funding for sustainable innovation. This variable is measured as the ratio of operating profit to operating income. Firms with long-term debt contracts may diminish financial constraints. These firms with long-term debt ratio are more likely to engage in R&D and they may be more prone to apply for public R&D subsidies. In summary, those variables affecting R&D activities are dealt as control variables, showed in Table 1.

R&D data come from the report of the director board. Government R&D subsidies include the incentives for new product development, loan interest and so on, which have a direct relationship with the enterprises' technological innovation. The human capital data, such as the proportion of undergraduate of enterprises are also manually from listing corporation annual report and other data from GTA data, which is developed specifically for China's financial and economic research by Tai'an company according to the international standard database (CRSP and COMPUSTAT).

3.3. Model

For Hypothesis 1, we constructed model (1), taking external R&D investment as the dependent variable and multiple regression analyses were performed to test it; The mean differences on the strength of government R&D subsidies under different ownership properties were analyzed by *t*-test to verify Hypothesis 2; For Hypothesis 3, we added the interaction of the ownership nature and government R&D subsidies based on the first model for the multivariate regression analysis, namely model (2).

$$exrd_t = \alpha_0 + \alpha_1 rdsub_{t-1} + \alpha_2 control + \varepsilon_t \quad (1)$$

$$exrd_t = \alpha_0 + \alpha_1 rdsub_{t-1} + \alpha_2 rdsub_{t-1} \times own_t + \alpha_3 control + \varepsilon_t \quad (2)$$

Table 1
Variable definition.

Variable name	Variable index	Definition
Government R&D subsidy intensity	*rdsub*	Government subsidies as a percentage of total assets
External R&D investment	*exrd*	The ratio of the amount of loans for S&T activities of financial institutions to operating income
Scale	*lnasset*	The logarithm of total assets
Market competition	*sellra*	The ratio of sale expenditure to operating income
Own nature	*own*	This variable is coded 1 if the firm is actual controlled by private, otherwise this variable is coded 0.
Age	*age*	Years since the setup of enterprises
Human capital	*bkra*	The employee proportion with bachelor degree or above
Operating profit ratio	*opera*	The ratio of operating profit to operating income
Long-term debt ratio	*debt*	Long-term debt as a percentage of total assets

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Table 2
Descriptive statistics of the variables.

Variables	Mean value	Standard variation	Minimum value	Maximum value	Median
exrd	0.007	0.007	0	0.0598	0.0061
rdsub	0.005	0.006	0.0001	0.0463	0.0034
lnasset	25.80	0.839	19.10	29.56	25.63
sellra	0.064	0.062	0	0.339	0.0450
age	10.625	4.793	3	26	9
bkra	0.241	0.216	0.0092	0.947	0.171
debt	0.385	0.189	0.0171	0.898	0.382
opera	0.121	0.140	−0.490	0.679	0.0962
own	0.684	0.478	0	1	1

4. Empirical analysis

4.1. Descriptive statistics

Table 2 provides descriptive statistics. It shows that the mean value of external R&D investment is 0.72%, indicating that the amount loans of financial institutions for S&T activities is in a relatively low level compared with enterprises current operating income. The mean intensity of R&D subsidies is 0.51%, showing that the government has carried on some R&D subsidies to enterprises. Table 3 shows the results of the correlation between independent variables and external R&D investment. The result shows that external R&D investment has a positive relationship with government subsidies for R&D at the 1% level of significant, the correlation coefficient between the variables are below 0.4, indicating that the model does not exist serious multicollinearity problem, can be used to do further analysis.

4.2. Multiple regression analysis

Model 1 in Table 4 is the results of ordinary least squares regression analysis, all of the estimated results of the parameters are corrected through heteroscedasticity-robust standard errors. The results show that the external R&D investment has a significant positive association with government R&D subsidies at the 1% level, suggesting to support Hypothesis 1. The regression results of control variables show that the market competition is advantageous for the enterprise to attract external investment in R&D, the control variables of enterprise scale, profitability and human capital all have significantly positive impact to external R&D investment, however, the variables of both asset liability ratio and enterprise age have significantly negative association with external R&D investment, in short, all of the results are consistent with the existing research conclusions.

4.3. Hypothesis testing of the difference between two R&D subsidies means

The means of two government R&D subsidies strength under different nature of ownership is tested, the results show that the rate of government R&D subsidies of SOEs to enterprises total assets is 0.0057, and that of private enterprises is 0.0046, which indicates that there are significant difference between SOEs and private enterprises under 1% of the significance levels (T value = 2.442***). The government put the limited government subsidy resources to support SOEs with R&D activities, SOEs can gain more R&D subsidies than private firms, supporting the Hypothesis 2.

4.4. Impact of ownership nature

The interaction of ownership nature and government R&D subsidies is added to model 2 (Table 4) based on model 1, the result of regression shows that the coefficient was significantly positive (0.342, in the 5% level), suggesting that compared with SOEs, government R&D subsidies to private enterprise can promote more external R&D investment, which supports Hypothesis 3.

4.5. Robustness test

The measure of dependent and independent variables may influence the conclusion, so different measures of them were taken to test robustness. The intense of government R&D subsidies is measured with government subsidies as a percentage of total assets previously, to test robustness, it is measured as a percentage of operating income. Similarly, the external R&D investment by funding for S&T activities of financial institutions is the ratio of the amount of loans to operating income, which is replaced by the ratio to total assets in the process of robustness test. As in the enterprise performance measurement, the managers of enterprises may carry on the earnings management to operating income when they are under pressure. According to the basic model in this paper, the regression results are showed in Table 5.

In model 3, the regression coefficient of government R&D subsidies is 0.411, having a significant positive correlation with enterprise external R&D investment, which confirms that the government subsidies provides a positive signal of R&D quality and induces easy access to external R&D investment, supporting for H1. Model 4 shows that the regression coefficient of the interaction of ownership nature and government R&D subsidies is 0.334, significantly positive to external R&D investment, suggesting that government R&D subsidies to private enterprises can induce more external R&D investment than that to SOEs, which provides further evidence for H3. To sum up, the conclusion of this paper is robust.

5. Discussion, conclusion and limitation

This paper studies the signal/certification effect of government R&D subsidies and explores whether SOEs can gain more subsidies than private enterprises and whether the ownership nature impacts the signal effect of R&D subsidies taking the evidence from Chinese listed corporations. Chinese transition economy provides a favorable context to empirically test whether the government program meets its objectives. Our results show that receiving R&D subsidies increases the possibility of enterprises' external finance. What's more, SOEs can receive more

Table 3
Pearson correlation coefficient of the variables.

Variables	*exrd*	*rdsub*	*lnasset*	*sellra*	*age*	*bkra*	*debt*	*opera*	*own*
exrd	1								
rdsub	.342**	1							
lnasset	0.054*	0.037*	1						
sellra	0.014	−0.108	−0.048	1					
age	0.131**	.330**	.190**	−0.012	1				
bkra	0.092*	.254**	0.026	−0.082	.390**	1			
debt	−0.094	−.315	0.128*	0.044	.381*	.392	1		
opera	.054**	.396**	.031*	0.032	.329**	.334**	.379**	1	
own	−0.157*	−0.301**	−0.103	−0.093	−.097*	.369**	−.385*	.230**	1

** Significant correlation at 0.01 level (bilateral).
* Significant correlation at 0.05 level (bilateral).

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Table 4
Regression analysis.

Variables	Model 1		Model 2	
	Coefficient	T value	Coefficient	T value
constants	0.182***	5.06	0.123***	3.32
rdsub	0.402***	2.65	0.641*	1.93
lnasset	0.007***	4.01	0.007***	3.78
sellra	0.072**	2.37	0.072**	2.37
age	−0.001***	−2.63	−0.001**	−2.42
bkra	0.062***	6.97	0.063***	7.04
debt	−0.032***	−3.52	−0.034***	−3.71
opera	0.046***	2.73	0.044***	2.62
own	−0.004	−1.41	−0.002	−1.04
own × rdsub			0.342**	1.99
sample		485		
F value		18.21***	16.57***	
R^2		0.413	0.415	

*** Significant correlation at 0 .01 level (bilateral).
** Significant correlation at 0.05 level (bilateral).
* Significant correlation at 0.10 level (bilateral).

subsidies than private enterprises, which indicates that there are some preferences and unfairness in R&D subsides. However, the signal effect of R&D grants is stronger in private enterprises than that in SOEs. Summary, government R&D subsidies thus generate a significant signal/certification effect to external financiers and the ownership nature does matter to the effect. Our results are robust to a series of alternative explanations. This study contributes to the literature in the following aspects.

Firstly, it provides new insights for the signal/certification effect of R&D subsidies, our empirical evidence shows that obtaining an R&D grant provides a positive influence, which is advantageous for the enterprises' access to the follow-up financing. That is to say, the research indicates that the government R&D subsidies can serve as a signal for attracting external investment in R&D, certifying the high-quality and bright prospects of the projects, namely the signal/certification effect. Both of the development of enterprises and economic growth depend on getting adequate external financing for enterprises' innovative investments, and the result indicate that receiving subsidy increases the likelihood of obtaining external investment, so the government should consider this effect when building the R&D funding policies.

Secondly, the results indicate that SOEs can generally receive more R&D subsidies than private enterprises in China, and the causes are analyzed. As Shu et al. (2016) argues, government support and social legitimacy are probably the two most important institutional benefits in China. This evidence helps us understand institutional constraints on market efficiency, providing empirical evidence to the theory of the government R&D subsidies to correct market failure.

Table 5
Robustness test results.

Variables	Model 3		Model 4	
	Coefficient	T value	Coefficient	T value
constants	0.173***	4.92	0.131***	3.37
rdsub	0.411**	2.40	0.632*	1.94
lnasset	0.006**	2.41	0.006**	2.43
sellra	0.069**	2.36	0.069***	2.38
age	−0.001**	−2.43	−0.001**	−2.32
bkra	0.060***	6.67	0.060***	6.84
debt	−0.030***	−3.50	−0.030***	−3.63
opera	0.042**	2.33	0.040**	2.32
own	−0.005	−1.46	−0.004	−1.09
own × rdsub			0.334**	1.97
Sample		485		
F value		17.98***	16.02***	
R^2		0.401	0.397	

*** Significant correlation at .01 level (bilateral).
** Significant correlation at .05 level (bilateral).
* Significant correlation at 0.10 level (bilateral).

Thirdly, it adds to the literature on the link of ownership nature and R&D subsidies research by focusing on the R&D subsidies signal/certification effect on different ownership nature in China. Broadly, the economic consequences of government relationships in a transitional economy is examined in this paper. An increasing number of studies focus on how political and economic systems affect the behavior of market participants (e.g., Shleifer, 1998; Faccio, 2006; Chen et al., 2014). And we develop new evidence by showing that the signal/certification effect of R&D grants is stronger in private enterprises than that in SOEs. Similarly, Zhang et al. (2014) examine the relationships among political connections, government subsidies and firm financial performance, finding that a government background of firm executives weakens subsidy effects. In addition, there are several policy implications as follows.

Compared with some of the developed countries, both the R&D investment and government's input to S&T in China are insufficient, so the government should continue to strengthen the government R&D subsidies, and special attention should be paid to the private enterprises, at the same time improving the management mechanism of SOEs. The results show that the positive R&D subsidies effect is more significant in private enterprises than that in SOEs, thus the government should pay more attention to R&D activities of private enterprises, and the subsidy policy can be partial to the high-quality private enterprise projects. In addition, the government should improve the R&D subsidy project evaluation and selection mechanism, ensuring that R&D project selection is open and fair. Both of improving the transparency in subsidy selection process and strengthening public supervision of R&D subsidy projects are necessary for governments, which can not only reduce the principal-agent problem in the process of R&D project selection, but provide confidence for the external investors identifying high-quality R&D projects and investing in R&D activities.

For the signal/certification effect of R&D subsidies, we can think about the causality furtherly, that is to say, obtaining an R&D grant increases the enterprises' external financing, or it is just on the contrary: external investors require R&D subsidies as a prerequisite for financing? From the interviews with external investors, the results indicate that while the external investors stimulate firms to apply for subsidies, obtaining the subsidies is definitely not a prerequisite for attracting financing. Actually, the enterprises received government funding are mostly based on their R&D projects, which enable them to attract more private capital. The government often grants project specific funding and private investors are usually a typically operate at the firm level (Takalo and Tanayama, 2010). Our study is subject to some limitations.

First, due to lack of data, we just examine the impact of getting government grants on the firm's ability to attract external financing without considering the enterprises failed to get R&D subsidies, which is also an interesting topic to be explored in the future. Second, endogeneity problems may potentially bias our results. Does granting subsidy increase the likelihood of attracting external financing, or it is just the contrary, does the enterprises' financing need result in applying for subsidies? To eliminate this problem, we used lagged control variables in our analysis and we incorporated several variables in our analysis that explicitly control for the firm's external financing need.

Although SOEs play an important role in economic development, a large number of scholars are interested in the interaction between government subsidies and enterprises, however, few quantitative evaluations of the effectiveness of public R&D subsidy policies to different ownership have been touched in science, technology and innovation policy literatures. Obviously, there are a lot of research works in the future. More work is needed on the key factors on enterprises' applying for and obtaining funding, it is important for the accurate evaluation of the effects of public subsidies. From the maturity of the debt provided, the debt financing includes short term and long term debt financing. Is the positive impact of the signal/certification effect generated by receiving an R&D subsidy same for them in different ownerships? This

Please cite this article as: Wu, A., The signal effect of Government R&D Subsidies in China: Do ownership matter?, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.08.033

research needs large and complete datasets, containing information for applicants and subsidies for specific types.

A broader investigation of behavioural additionality includes obtaining subsidies and their impact on a firm's ability to raise money. For example, a detailed analysis for different types of financing is useful, equity financing can be distinguished from the old shareholders or new investors, venture capital, various types of bank debt, etc. A further explore of what kind of companies, financiers or market characteristics affect the signal effect of subsidies will also be of value. In this paper, we just distinguish the subsidies effect between state-owned and private enterprises, in the future we may utilize a comprehensive treatment of ownership characteristics or a wide range of ownership structures (Choi et al., 2011, 2012), overcoming weakness in previous studies that have used a more narrow focus of one or two types of ownership. In addition, the effect of R&D subsidies to green innovation (Schiederig et al., 2012) and sustainable innovation (Ketata et al., 2015) are also valuable topics for future study.

Funding

This work was supported by National Natural Science Foundation of China (NSFC) under the Grant No. 71203083 and 71632004, it was also supported by social science planning project of Shandong Province under the Grant No. 16CGLJ04.

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Aihua Wu is a Professor in the School of Business at the Ludong University, Director of Financial Management Department at the same University and she was also a visiting professor in Ohio University from July 2015 to January 2016. She earned her PhD degree in business administration from the Glorious Sun School of Business & Management at the Donghua University and graduated from Dalian University of Technology with M.A. degree. Her research interests mainly focus on technological innovation, energy and logistics, financial management etc. She has authored or co-authored three books, many journal articles such as *Technology Analysis & Strategic Management*, *Journal of High Technology Management Research*, *Energy Efficiency*, *International Journal of Shipping and Transport Logistics*, etc.

Please cite this article as: Wu, A., The signal effect of Government R&D Subsidies in China: Do ownership matter?, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.08.033