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The Impact of Government Subsidies and Enterprises' R&D Investment: A Panel Data Study from Renewable Energy in China

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Abstract

In this research, we aim to understand the influence of government subsidies on enterprises' research and development (R&D) investment behavior, particularly in China's renewable energy sector. We are also interested in examining how the attributes of enterprise ownership act as a moderating variable for the relationship between government subsidies and R&D investment behavior. Three classical panel data analysis models including the pooled ordinary least squares (OLS) model, the fixed effect model and the random effect model are employed. We find that government subsidies have a significant crowding out influence on enterprises' R&D investment behavior and that the influence is further moderated by the attributes of enterprise ownership. Moreover, a panel threshold regression model is used to demonstrate how the influence of government subsidies on enterprises' R&D investment behavior will change when government subsidies increase. Two thresholds, 0.6% and 10.1%, are identified. We recommend that relevant government departments should motivate enterprise R&D investment behavioral intention by increasing subsidies within a certain range. Different attributes of enterprise ownership should also be considered as part of policy reform and re-structuring relating to government subsidies.

Keywords: renewable energy, enterprise, government subsidy, ownership, R&D investment, threshold effect.

1. Introduction

The G7 countries have formulated a series of policies to support firms in the renewable energy industry. For example, U.S. President Obama released an ambitious 2016 Federal Government Budget Proposal to invest $7.4 billion in clean energy technology programs across all agencies (Laporte, 2015). Japan and the European Commission also published relevant policies and national programs to help renewable energy firms achieve sustainable development (see EU renewable energy policy, 2015). Consequently, fierce international energy competition and a quick increase in China's domestic energy demand have drawn the attention of various Chinese government departments including the State Council of China, the Bureau of Energy and The Ministry of Environmental Protection of China. The Chinese central government has recently urged these departments to collaborate together to consider various policies and specific measures for promoting the development of renewable energy.

Since the Renewable Energy Law of the People's Republic of China was enacted in 2005, the Chinese government announced a series of subsidy policies to boost the renewable energy industry (Shen and Luo, 2015). Generally speaking, government subsidies may be offered through direct or indirect supporting approaches in terms of funding allocation, such as VAT returns, fiscal subsidies, tax incentives for innovation, price control, demand assurance and compulsory allocation (Zhang et al., 2014; Shen and Luo, 2015). Moreover, government can set up specified subsidies for different industries and at business development stages, such as subsides for the development

of renewable energy technologies. In this research, the term "government subsidies" mainly refers to public R&D research funding granted by Chinese central and local government departments for enterprises to develop new technologies of renewable energy and relevant innovative activities. This is our research focus because we believe that the development of emerging and cutting-edge renewable energy technologies plays a pivotal role in ensuring green, sustainable, renewable energy development. Recent studies show that the average research and development (R&D) intensity of international renewable energy enterprises is higher than that of Chinese listed renewable enterprises. The average research and development (R&D) intensity of Chinese listed renewable enterprises is only 0.76% and so the main barrier for R&D and innovation in the renewable energy industry in China is cost (Costa-Campi et al., 2014).

Despite the growing significance of government subsidies in solving the shortage of private R&D investment of renewable energy enterprises, there is limited understanding of the impact of government subsidies on renewable energy enterprises' behavioral intention to strengthen R&D at the micro-level. A systematic literature review of prior studies on renewable energy development and government subsidies was undertaken that resulted in the identification of a research gap. Existing research on renewable energy development has mainly focused on exploring various energy policy instruments and the effect of portfolio standards on climate and energy industry development in developed countries and regions, such as the United States (Menyah and Wolde-Rufael, 2010; Roe et al., 2001; Bang, 2010) and the European Union

(Jacobsson et al., 2009; Haas et al., 2004; Reiche and Bechberger, 2004). We contend that such findings may not be the same for China. A few other researchers have further examined the potential macroeconomic influence of renewable energy policies on the energy industry in developing countries (e.g., Zhang et al., 2009Wang et al., 2010; Cherni and Kentish, 2007; Zhao et al., 2011). As noted earlier, due to the lack of understanding of the exact effect of government subsidies on enterprises' intention to strengthen R&D investment at the micro level, it is still unclear how the R&D level of firms with government subsidies is to be compared with that of firms without government subsidies. Specifically we want to know if the relationship between government subsidies and enterprises' intention to strengthen R&D investment is linearly correlated and if government subsides complement or substitute private R&D investment. These two questions have important implications for the implementation of appropriate policies of government subsidies in developing countries. There is a dearth of literature investigating the above-mentioned issues.

In this study, we address the gap in prior research by investigating the influence of government technology development subsidies on enterprises' R&D investment behavior, focusing on China's renewable energy sector. Moreover, we are also interested in examining how the attributes of enterprise ownership moderate the relationship between government subsidies and enterprises' R&D investment behavior. Unlike renewable energy enterprises in developed countries, Chinese renewable energy enterprises inherently have different types of ownership due to the unique institutional environment and political background. The amount of government

subsidies acquired by renewable energy manufacturers with different attributes of ownership may vary greatly. Specifically, the more a company has a close relationship with the Chinese central government, the more financial support this company can obtain. In addition, we further examine how these factors – including government subsidies, enterprise ownership attributes, and political connections of enterprise owners – work together and demonstrate an interactive effect on enterprise R&D investment.

Our paper proceeds as follows. The next section reviews the theoretical foundation for the study. The third section describes the research methodology employed in the investigation. Section 4 provides the results of our data analysis and this is followed by a summary of our research findings in section 5. The final section rounds off with a discussion of the contributions and policy implications of our research.

2. Literature Review

In this section we consider government subsidies for renewable technology development, their impact on private enterprises, and the influence of firm ownership.

2.1. Government subsidies for renewable energy technology development

The effect of government subsidies for technology development has been extensively examined in prior studies from different aspects, such as increasing the rate of green innovation (Johnstone et al., 2010; Aalbers et al., 2013), improving the value of renewable power technologies (Davis and Owens 2003), promoting the market diffusion of a niche renewable energy technology (Bointner, 2014) and increasing international trades and domestic R&D (Kim and Kim, 2015).

2.2. Differential effect of government subsidies on enterprises' private R&D investment

Prior studies show that the actual effect of government subsidies on improving enterprise private R&D investment considerably varies across industries. For instance, Arias and van Beers (2013) found a negative relationship between government subsidies and some renewable energy firms' R&D in terms of the amount of renewable energy technology inventions and patents, particularly those related to the solar and wind renewable energy sector. Saul's (2002) empirical data from Israeli manufacturing enterprises in the 1990s indicated that firms were more like to increase their private R&D investment over the long-term provided that they could concurrently obtain funding from the Israeli Ministry of Industry and Trade. In other words, government subsidies should be viewed as an alternative funding source instead of replacing enterprises' private R&D investment (Koga, 2005). Interestingly, some studies found inconsistent empirical findings where government subsidies have

a negative (i.e. crowding-out) (Goolsbee, 1998; Kelette et al., 2000) or limited effect (Wallsten, 2000) on enterprises' private R&D investment. Moreover, some elements of context (e.g., the background of industries and country characteristics) have a moderating effect on the relationship government subsidies and enterprises' private R&D investment (Czarnitzki and Toole, 2007; Görg and Strobl, 2007; Czarnitzki et al., 2007).

2.3. Ownership influence on enterprises' R&D activities and subsidies received

During the economic transition process over the past two decades, China has formed a special institution in which company ownership characteristics directly affect their R&D performance and subsequent innovation activities. Compared with other kinds of enterprises (e.g., private enterprises), state-owned enterprises even stress how to innovate effectively and efficiently because they have huge political resources that are rather useful for obtaining government subsidies (Yu et al., 2010; Wu and Liu, 201 and Wu et al., 2012).

3. Research Method

3.1. Research design

We chose to conduct longitudinal research to examine the delayed effect of government subsidies on enterprises' private R&D investment behavior. Such a longitudinal analysis design will allow us to identify and compare the influence of

government subsidies on enterprises private R&D investment behavioral intention at different stages (Doh and Kim, 2014; Lee and Cin, 2010; David et al., 2000). In this research, we decided to introduce a lag variable demonstrating the effect of government subsidies within 0 to 1 year. Specifically, private R&D investment in year t is influenced by government subsidies in previous years: t, t-1 and t-2. We hypothesize that government subsidies should have a direct effect on enterprises' behavioral intention to increase R&D investment during the first and second half-years after they obtain funding. As noted earlier, prior studies employing different research methods found that the effect of government subsidies on enterprises R&D investment varies. For example, linear regression methods have been extensively employed to examine the effect of government subsidies on motivating enterprises' private R&D investment (Wolff and Reinthaler, 2008). We argue that such linear regression methods ignore the moderating role of subsidy intensity on the relationship between government subsidies and enterprises' private R&D investment behavioral intentions. Therefore, we adopt the panel threshold regression (PTR) method proposed by Hansen (1999) to examine the threshold effect of subsidy intensity on moderating the relationship between government subsidies and enterprises' private R&D investment.

Traditional methods employed by prior studies more or less assume that government subsidies are randomly allocated to all eligible enterprises. However, this is not always the case, because policymakers often determine the allocation model of government funding resources. The amount of subsidies for a firm will be

significantly influenced by the firm's ownership attributes and political background. In order to explore the interactive role of government subsidies, we employ a semiannual panel dataset over the period from June 2009 to December 2014. A panel data regression is carried out to examine how government subsides influence an enterprise's intention to increase private R&D investment toward a positive (i.e. complementary) or negative (i.e. crowding-out) effect. In addition, government subsidies usually demonstrate a lagged effect on a firm's innovative activities and R&D investment. For that, we add a lag variable for government subsidies in the model in this study (see section 3.3 for the full model). Moreover, in order to ascertain how Chinese market characteristics and the institutional environment influence the relationships among firm ownership attributes, firm types and government subsidies, a threshold regression model is developed for non-dynamic panels with individual-specific fixed-effects. In this research, we use this model to examine the differential effects of government subsidies on enterprises' private R&D investment under different subsidy intensities. A time frame is chosen due to limited high quality data resources. This time frame demonstrates key phases of the development of domestic renewable industries supported by the Chinese government.

3.2. Data

Data was collected from renewable energy enterprises listed on the Shanghai and Shenzhen stock exchanges. Through semiannual panel data collection over the period from June 2009 to December 2014, relevant information on private R&D investment

and the amount of government subsidies for renewable energy enterprises were provided by Wind Information Co. Ltd (Wind Info[1]), located in the Lujiazui Financial Center in Shanghai. Wind Info. is a leading integrated service provider of financial data, information, and software. Data with missing key values were removed and 172 completed cases were finally collected. Moreover, we only consider enterprises that have received subsidies for at least twelve consecutive half-years to examine the differential effect of government subsidies on enterprises' private R&D investment. As a result, the financial data for 147 renewable energy enterprises was finally used in our study.

Background information on firms, ownership characteristics and types of actual firm owners were manually collected from company annual reports. A further triangulation was carried out based on information found on the official websites of enterprises. All estimations were calculated using Stata 11.

3.3. Panel Regression Model

Our panel regression model is given in equation 1. In this section we will explain the model.

$$\begin{aligned} R\&Dput_{i,t} &= \alpha_1 GS_{i,t} + \alpha_2 GS_{i,t-1} + \alpha_3 GS_{i,t-2} + \beta_1 income_{i,t} \\ &+ \beta_2 topshare_{i,t} + \beta_3 roa_{i,t} + \beta_4 scalenum_{i,t} + \chi_1 CT + \chi_2 PR \\ &+ \phi_1 GS_{i,t-1} * CT + \phi_2 GS_{i,t-2} * CT + \phi_3 GS_{i,t} * PR + u_i + \varepsilon_{i,t} \end{aligned} \quad (1)$$

[1]Wind Info. has built up a substantial, highly-accurate, first-class financial database, which includes stocks, funds, bonds, FX, insurance, futures, derivatives, commodities, and macroeconomic and financial news. Moreover, institutional investors can acquire the latest information via regular updates provided by Wind Info.

3.3.1. Dependent variable

$\mathrm{R\&Dput}_{it}$ represents the private R&D investment of enterprise *i* in the period *t*. Private R&D investment refers to R&D staff's innovative ideas, information and other intangible elements, which are difficult to accurately measure. However, enterprises have to spend considerable funding to ensure these subjective elements. Thus, private R&D investment may be viewed as an indicator of the relative strength of enterprises R&D spending. Prior studies on measuring private R&D investment usually use the amount of R&D expenditure of enterprises during a certain period as a dependent variable.

3.3.2. Explanatory variables

$GS_{i,t}$ represents the amount of government subsidies of enterprise *i* in the period *t*; $GS_{i,t-1}$ and $GS_{i,t-2}$ represent the amount of government subsidies of enterprise *i* in the t-1 and t-2 lagged periods, respectively. Data on government subsides for new technology development and transfer were empirically obtained from listed enterprises' semi-annual reports. $income_{i,t}$ refers to the amount of business income of enterprise *i* in the period *t*; $topshare_{i,t}$ refers to shares of the largest shareholder of enterprise *i* in the period *t*; $roa_{i,t}$ represents the return on assets of enterprise *i* in the period *t*, which includes return on total assets, return on total core assets, return on net assets and return on total net worth; $scalenum_{i,t}$ represents the total number of staff of enterprise *i* in the period *t*.

The criteria for identifying these variables are as follows:

(1) Considering the effect of government subsidies on the private R&D investment is usually delayed, we thus introduced $GS_{i,t-1}$ and $GS_{i,t-2}$ into the panel model, to capture a lagged effect as they have been used in previous studies (Antonelli & Crespi, 2013; Montmartin & Herrera, 2015; Colombo et al., 2013);

(2) The amount of firms' private R&D investment is usually influenced by firm scale. Researchers often find that firms with a large scale have a risk-taking attitude, and are willing to add to R&D investment. Thus, we introduced the variable $scalenum_{i,t}$ into the panel model;

(3) The amount of R&D private investment is usually constrained by annual income and Return on Assets (ROA), both of which we assume have a positive effect on R&D private investment. Thus, we introduced these two variables, $income_{i,t}$ and $roa_{i,t}$, into the panel model; and

(4) The share of the largest shareholder reflects capital centralization and the efficiency of resource allocation. We estimate that over-centralization of the capital will negatively influence private R&D investment. Thus, we introduced a variable called $topshare_{i,t}$ into the panel model. The definitions of the variables are show in Table 1.

Please Insert Table 1 in Here

3.3.3. Interaction terms

In this model, we identify three interactions among government subsidies, lagged government subsidies, enterprise ownership attributes, and owners' political connections. We believe that firm ownership characteristics and owners' political connections affect the amount of subsidies they can obtain from the Chinese government. In addition, the willingness of renewable energy enterprises to increase private R&D investment in China depends on their political resources to some degree. We use a dummy variable, *CT*, to indicate the degree of owners' political connections based on their background scored on a 7-point Likert scale with a score of 7 indicating 'the strongest political connections' and a score of 1 indicating 'the weakest political connections'. Another dummy variable, *PR*, refers to a set of legal rights of a firm and its possession of assets (Claessens et al., 2008; Marcelin and Mathur, 2015). This dummy variable takes the value of 1 if a firm is state-owned and 0 otherwise. u_i refers to an "enterprise individual effect" including entrepreneurship, innovation background and motivation. $\varepsilon_{i,t}$ indicates error terms.

3.4. Threshold regression model

Our threshold regression model is shown in equation 2.

$$R\&Dinput_{it} = \alpha_0 + \alpha_1 GS_{i,t-1} * I(\text{Support}_{it} \le r) + \alpha_2 GS_{i,t-1} * I(\text{Support}_{it} > r) + \theta x_{it} + \xi_{it} \quad (2)$$

We hypothesize that the relationship between government subsidies and enterprises' intentions to add private R&D investment is unlikely to be a linear relationship. Specifically, we ask: (1) *Is there an optimal interval for the supporting*

degree of government subsidies? and (2) *Is there a crowding-out or incentive effect on the relationship between government subsidies and enterprises' R&D investment as the amount of government subsidies change?* We assume that there is a threshold level of r, and the effect of government subsidies on improving enterprises' R&D activities will change significantly when the amount of government subsidies ($Support_{it}$) is more than r. We introduce a dummy variable called D_{it}. When $Support_{it} \le r$, D_{it}=1; otherwise, D_{it}=0. We define $I_t(r) = \{Support_{it} \le r\}$, of which, I (*) is an indicative function. If $Support_{it} \le r$, then I (*) takes value 1, otherwise it is 0.

In the threshold regression model, variable *i* represents an enterprise *i* and variable *t* represents the time period. *Support* is a threshold variable and *r* is a specific threshold value. Variable *x* is a set of controlling variables including the number of total staff, business income, return on assets, shares of the largest shareholder, enterprise ownership attributes, and owners' political connections; α_1 and α_2 respectively refer to the influence ratio of explanatory variables by explained variables of threshold variables $Support_{it}$ when $Support_{it} \le r$ and $Support_{it} > r$. ξ_{it} refers to stochastic disturbance. It is noted that although our threshold model only includes one threshold value, two or more threshold values possibly exist in practice. In this research, we set a double threshold regression model as:

$$R\&Dinput_{it} = \alpha_0 + \alpha_1 GS_{i,t-1} * I(\text{Support}_{it} \le r_1) + \alpha_2 GS_{i,t-1} * I(r_1 < \text{Support}_{it} \le r_2) + \alpha_3 GS_{i,t-1} * I(Support_{it} > r_2) + \theta x_{it} + \xi_{it} \quad (3)$$

In function $r_1 < r_2$ we argue that multiple threshold models can be further developed based on the above single and double threshold models.

4. Results

4.1. Descriptive statistical analysis

Descriptive statistics and correlation coefficients are shown in Tables 2 and 3. Means, standard deviations, maximum and minimum values are summarized for all variables in Table 3. Pairwise correlation coefficients with significance levels are also provided. Moreover, variance inflation factors (VIFs) are used to examine bias estimates derived from multicollinearity, where two or more variables in a multiple regression model are highly correlated. Under this situation, the coefficient estimates of multiple regressions may change in response to a small change. We computed the VIFs and found most to be around 2 and less than the conservative threshold of 5. The computed VIFs suggest that multicollinearity was not a major issue in our study.

Please Insert Table 2 in Here

Please Insert Table 3 in Here

4.2. Regression analysis

According to the basic model (1), we implemented a regression analysis based on panel data for new energy enterprises from 2009 to 2014 as shown in Table 4. A Hausman test was carried out ($p=0.0243$) and indicated that a fixed effect model should be adopted.

Please Insert Table 4 in Here

A White's (1980) test for heteroscedasticity showed positive results ($p<.001$). Thus, compared with a fixed effects model, a heteroscedasticity robust model could

provide a more accurate estimation of the relationship between government subsidies and the private R&D investment of energy enterprises.

As shown in Table 4, the coefficient for government subsidies and enterprises' private investment in the current period is -0.038. This result means that if the government increases subsidies by 1%, renewable energy enterprises are likely to reduce their private R&D investment by 0.038%. Moreover, a lagged crowding-out effect was found at the 1% level of significance. An increase in government subsidies by 1% will lead to 0.66% and 1.098% reductions in private R&D investment during periods t-1 and t-2 respectively. Such a significant lagged crowing-out effect means that Chinese renewable energy firms are not willing to take risks in initial R&D stages because of high costs. Compared to developed countries, the Chinese government acts as a key driver for the renewable energy sector and offers the majority of R&D investment for enterprises. Thus, the Chinese government needs to consider appropriate policies to encourage enterprises' intentions to increase the funding of R&D.

Our research findings showed that the relationship between enterprises' property rights and government subsidies is significant at the 1% level. The relationship between owners' political networks and government subsidies is also significant in the t-1 and t-2 lagged periods ($p<.01$). This means that owners' personal political connections play a role in obtaining government subsidies. In practice, enterprises don't have an equal opportunity to obtain government funding, particularly in China where the institutional environment is distinctive. Further, we found that a firm's

political background and network also demonstrates an important role in obtaining other types of funding, such as bank loans (Li et al., 2008). As a result, more and more Chinese firms in the renewable energy industry are willing to spend considerable effort in establishing relationships with different Chinese government departments.

In order to further examine the influence of firm ownership attributes, we divided the sample into two groups (state-owned and non-state-owned). Through descriptive statistics, we found that the average amount of government subsidies for the state-owned group and the non-state-owned group are 3637.336 and 1580.175 ten thousand Chinese Yuan, respectively. The average intensity of government subsidies is similar in both groups: 0.010 and 0.019 for the state-owned group and for the non state-owned group, respectively. Thus, our research findings suggest that ownership attributes have a weak effect on helping firms to obtain government subsidies.

Please Insert Table 5 in Here

We found that the nature of firm ownership directly determines the effect of government subsidies on firms' R&D investment behavior. For example, for a state-owned new energy firm, the incentive effect of government subsidies on the firm's R&D activities in the current period is 0.533, with a significant level of 1%. However, this effect was significantly reduced for a non-state-owned new energy firm. Our empirical findings found that lagged government subsidies for a firm during one period have a significant crowding-out effect on the firm's R&D

investment:-1.396 for the state-owned group and -0.355 for the non-state-owned group (p<.01). The different effects (i.e. incentive vs. crowding-out) for these two types of firms may be due to organizational heterogeneity.

4.3. Results of the threshold estimation

Estimation of two threshold values is shown in Table 6. Single and double threshold effects were both found at the significant level of 1%, while the triple threshold effect was not significant. Threshold values of government subsidy intensity (i.e. 0.6% and 10.1%) were achieved by bootstrap estimation. According to the two threshold values, government subsidies could be divided into three groups including low subsidy (less than 0.6%), medium subsidy (greater than 0.6% and less than 10.1%) and high subsidy (greater than 10.1%).

Please Insert Table 6 in Here

Please Insert Table 7 in Here

Please Insert Table 8 in Here

According to the three intervals divided by each threshold, the contribution of the degree of government subsidies for firms' innovation investment was significant at the 5% level (see Table 7). When the intensity of government subsidy was less than 0.6%, government funding support behavior showed a significant crowding-out effect (i.e. -0.315, p<0.001) on a firm's R&D investment activities associated with slight marginal effects. Our empirical data show that if government subsidy intensity reached 0.6%, the crowding-out effect disappeared and a significant incentive effect of government subsidies (i.e. 0.139***) on the firm's R&D investment activities was

created until government subsidy intensity exceeded 10.1%. In addition, prior marginal effect reaches maximum value. We see that when government subsidy intensity exceeded 10.1%, the government subsidies demonstrated a crowding-out effect again on the firm's R&D investment activities and the contribution degree was -0.259***.

5. Discussion

The results of our data analysis show that the effect of government subsidies on increasing enterprises' intention to invest in R&D is an inverted-U relationship. Moreover, firm owners will play an important role in helping a firm to obtain government subsidies if they have substantial political resources. Thus, in the renewable energy industry, we suggest that enterprises with poor political backgrounds should actively foster R&D activities and improve their own innovative capabilities, which may help to overcome the discrimination of government in obtaining funding. To increase the effectiveness of government subsidies, we recommend that governments should improve funding allocation mechanisms and place an emphasis on assessing applicant's research competency and innovative capability. Third, the two identified threshold effects (i.e. 0.6% and 10.1%) confirm the non-linear relationship between the intensity of government subsidies and its practical effect on increasing a firm's intention to do private R&D activities. In sum, our research findings fully support our hypotheses. Government subsidies create a crowding-out effect followed by an incentive effect. A crowding-out effect will appear again once the government subsidy intensity increases. This means that government should consider how to develop an appropriate subsidy policy for renewable energy enterprises, adapting to the dynamic characteristics of the subsidy effects. The Chinese government needs to avoid the 'Matthew effect' (Merton, 1968;

Antonelli & Crespi, 2013) when implementing government subsidies.

6. Conclusions and Policy Implications

This research makes several contributions, from both practical and theoretical perspectives. First, we examine the effect of government subsidies on micro innovative activities of renewable energy enterprises, and find that government subsidies have a significant crowding-out influence on enterprises' R&D investment behavior. Second, the moderating role of the political and institutional background of enterprises in the relationship between government subsidies and enterprise R&D investment is examined. Our research shows that the relationship between a firm's ownership and obtained government subsidies reaches a statistically significant level of 10% with a 0.341 value. The relationship between firm owners' political resources and government subsidies is at a significant level of 1% during the t-1 and t-2 lagged periods. Third, this research employs the non-standard asymptotic theory of inference and the bootstrap method to examine how the influence of government subsidies on new energy enterprises' R&D investment varies in accordance with the supporting degree of subsidies. The effect of government subsidies on increasing enterprises' intention to invest in R&D demonstrates an inverted-U relationship.

There are several limitations in this research. First, we only employ a semiannual panel dataset over the period from June 2009 to December 2014. Our research is based on this short panel dataset since the Wind database only records R&D data for the sample since 2009. Second, we don't further examine the incentive effect of subsidies on stimulating private R&D investment based on different subsidy types.

We believe that such a comparison among different kinds of subsidies is a possible avenue for future research.

The Chinese government is playing a pivotal role in promoting the development of renewable energy. An appropriate implementation of subsidy policies is essential for the growth and innovation of strategic emerging industries (SEIs). Some studies suggest that government subsidies have a crowding-out influence on enterprises' R&D investment while others noted that government subsidies have a positive impact on enterprises' own R&D investment. In this research, we employ estimations of pooled OLS, fixed effect, and random effect models to examine government subsidies' influence on the R&D investment of renewable energy enterprises. The moderating effect of ownership attributes on the above relationship was examined as well. We employed a panel threshold model to investigate the threshold effects of subsidy intensity on the relationship between government subsidies and enterprises' R&D investment.

A panel data consisted of 147 Chinese renewable energy enterprises from 2009 to 2014. Our empirical findings show that government subsidies have a significant crowding-out effect on new energy enterprises and have no incentive effect. Second, the moderating effect of enterprise owners' background characteristics on the relationship between government subsidies and enterprises' R&D investment was significant. Third, for enterprises with different ownership attributes, government subsidies have different effects on firms' private R&D investment. For example, government subsidies have a remarkable incentive effect on state-owned renewable

energy enterprises' R&D investment. However, a notable crowding-out effect for government subsidies on state-owned renewable energy enterprises' intention to increase private R&D investment was found. Finally, estimation results of the panel threshold model show that government subsidies have a nonlinear relationship with enterprise innovation investment. The influence of government subsidies on enterprise innovation investment will vary in accordance with government subsidy intensity. Generous government subsidies don't always result in incentive effects on renewable energy enterprises' private R&D investment.

Our empirical findings provide some policy implications. Considering a positive or negative effect on motivating renewable energy enterprises' R&D investment with the change of ownership and business background of enterprises, the Chinese government should apply appropriate government subsidy policies to enterprises with different business characteristics (e.g., a firm's business scale and development stage). For example, compared with private firms, the effect of government subsidies on increasing a university-run enterprise's intention forR&D investment should be obvious. This may be attributed to the fact that such kinds of firms (i.e. university-run enterprises) have a strong scientific research foundation and resources. Thus, it seems appropriate for governments to place an emphasis on increasing funding support for university-run enterprises.

This research also has some implications for policy implementations from the perspective of incentive mechanisms. According to our research findings, government subsidies indeed help enterprises that experience a serious shortage of specialized

research funding. Our study shows that enterprises with strong political background are likely to receive considerable government subsidies. It is necessary to improve current supervision mechanisms in order to reduce the possibility of senior managers' rent-seeking behavior. On the one hand, ensuring that the usage of subsidies is in accordance with relevant provisions and that information on government subsidies is fully disclosed to the public is imperative for the public supervision. Relevant government departments need to evaluate the efficiency of annual government subsidies, and keep on examining the usage of government subsidies. In order to reduce the possibilities of rent-seeking behavior, government departments should promote collective decision-making instead of individual decision-making.

The last contribution to policy of our research is how to identify suitable subsidy intensity. Our study shows that government subsidies do not always play an active role in improving the R&D capability of a firm, particularly in the later development stage of the firm. In other words, our research findings suggest that government should gradually reduce subsidy for a firm's R&D activities in the renewable energy industry as the firm develops. Other subsidy information including supporting duration and expected outcomes should be made clear as soon as possible.

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Table 1. Definition of variables

$R\&Dput_{it}$	the amount of renewable energy enterprise R&D Expenditure
$GS_{i,t}$	the amount of government R&D subsidies for enterprise i in the period t
$GS_{i,t-1}$	the amount of government R&D subsidies for enterprise i in the first lagged period of period t.
$GS_{i,t-2}$	the amount of government R&D subsidies for enterprise i in the second lagged periods of period t.
$income_{i,t}$	the amount of business income of enterprise i in the period t;
$topshare_{i,t}$	shares of the largest shareholder of enterprise i in the period t
$roa_{i,t}$	return on assets of enterprise i in the period t
Scalenum	the number of employees
CT	Dummy variable that takes 1 representing the weakest political connections and 7 representing the strongest political connections.
PR	Dummy variable that takes 1 if enterprises are state-owned, otherwise 0

Table 2. Descriptive statistics

Variables	Mean	Std. Dev.	Min	Max
R&D input(ten thousand)	4103.802	8128.015	0	128959.900
GS(ten thousand)	2289.681	5772.743	0	84270.030
Income（ten thousand）	156790.600	236411.200	0	2599373
Topshare（%）	32.876	15.000	0	86.830
ROA (%)	5.609	5.740	-68.064	48.979
Scalenum（individuals）	2326.542	2511.418	42	19682
CT	3.742	1.520	1	7
PR	0.350	0.477	0	1

Table 3. Pairwise correlations coefficients

Variables	R&Dinput	GS	GS_lag	GS_lag2	Income	Scalenum	Topshare	ROA	CT	PR	CTGSlag2	CTGSlag	GSPR
R&Dinput	1.0000												
GS	0.400	1.000											
	0.000												
GS_lag	0.214	0.435	1.000										
	0.000	0.000											
GS_lag2	0.385	0.521	0.550	1.000									
	0.000	0.000	0.000										
Income	0.735	0.483	0.273	0.465	1.000								
	0.000	0.000	0.000	0.000									
Scalenum	0.506	0.323	0.328	0.323	0.541	1.000							
	0.000	0.000	0.000	0.000	0.000								
Topshare	-0.020	0.161	0.163	0.161	0.129	-0.061	1.000						
	0.421	0.000	0.000	0.000	0.000	0.009							
ROA	0.099	0.110	-0.027	0.116	0.087	-0.053	0.093	1.000					
	0.000	0.000	0.258	0.000	0.000	0.017	0.000						
CT	0.160	-0.032	-0.034	-0.036	0.016	0.114	-0.042	-0.044	1.000				
	0.000	0.154	0.149	0.138	0.485	0.000	0.068	0.048					
PR	0.143	0.169	0.170	0.171	0.307	0.205	0.231	-0.150	-0.074	1.000			
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001				
CTGSlag2	0.544	0.763	0.582	0.627	0.505	0.397	0.113	0.103	0.125	0.148	1.000		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
CTGSlag	0.261	0.590	0.637	0.601	0.338	0.316	0.204	-0.031	-0.004	0.282	0.539	1.000	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.876	0.000	0.000		
GSPR	0.387	0.744	0.486	0.677	0.560	0.234	0.251	0.056	-0.055	0.378	0.585	0.588	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.013	0.000	0.000	0.000	

Table 4. Regression results of property nature, government subsidy and innovation investment of new energy enterprises

Variable	Heteroscedasticity robust model
GS	-0.038 (0.652)
$GS_{i,t-1}$	-0.660***
$GS_{i,t-2}$	-1.098***
$income_{i,t}$	0.022***
$topshare_{i,t}$	-48.441*
$roa_{i,t}$	31.233(0.212)
$scalenum_{i,t}$	1.105***
CT	-700.565***
PR	-2135.144***
$GS_{i,t-2}$*CT	0.209***
$GS_{i,t-1}$*CT	0.170***
$GS*PR$	0.341*
$\_cons$	3528.682*
$R\text{-}squared$	0.664
$Adj.\ R\text{-}squared$	0.661
N	1764
F	53.88

Note: The estimation method of is heteroscedastisity robust type model. * p<0.1， ** p<0.05， *** p<0.01。

Table 5. Government subsidy effect on R&D investment of enterprises with different ownerships

Variable (R&D investment)	State-owned group (PR=1)	Non state-owned group (PR=0)
GS	0.533***	-0.023(0.320)
GS_lag1	-1.396***	-0.355***
GS_lag2	-1.041***	-0.832**
income	0.018***	0.028***
topshare	-3.502(0.967)	-37.700*
roa	-104.530(0.302)	2.137(0.889)
scalenum	1.349***	0.683***
CTGSlag	0.252***	0.071**
CT	1563.484*	-1030.986***
CTGSlag2	0.201***	0.169**
_cons	-14891.8***	6592.272***
R-squared	0.6932	0.6498
Adjusted R-squared	0.6861	0.6462
N	444	1011
F	61.45	109.02

Note: *represents p<0.1，**p<0.05，***p<0.01

Table 6. Bootstrap of threshold effects

Threshold model	F value	P value	Critical value 1%	5%	10%
Single	86.365***	0.002	34.624	9.019	4.272
Double	58.671***	0.000	9.912	3.501	2.108
Triple	34.922	0.112	10.509	3.299	2.030

Table 7. Estimation results of threshold value

Threshold value	Estimation value	95% confidence interval
First one	0.006	（0.005 0.006）
Second one	0.101	(0.101 0.101)

Table 8. Estimation results of threshold effect of government subsidies on firms' R&D investment

Explanatory value (R&D investment)	Threshold model
income	0.0263***
scalenum	1.445***
topshare	- 9.251
roa	0.602
Govsupport	0.203***
CT	-299.267**
PR	-931.558
GS_lag_1	-0.315***
GS_lag _2	0.139***
GS_lag _3	-0.259***
_cons	-593.595
F value	284.590
Fixed effects test	F=10.30 Prob> F =0.0000