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Purchase Subsidies or R&D Subsidies? The Effect of Different Categories of Subsidies on Firm Innovation—A Focus on China's Electric Vehicle Subsidies

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Abstract

Using firm-level panel data on fiscal subsidies and R&D investment, this study employs a propensity score matching method to obtain a matched dataset. After a parametric estimation of the impact of different categories of subsidies (purchase subsides or R&D subsides) on innovation, the author finds that purchase subsidies for EVs have a significantly larger positive effect on firms' R&D investment than R&D subsidies for non-EVs. The mechanism of the impact of different categories of subsidies on innovation has also been investigated. Generally, the impact of EV subsidies on firms' intangibles is found to be significantly weaker than R&D subsidies for non-EVs whereas their effect on labor cost is significantly more pronounced. Results indicate that, purchase subsidies for EVs stimulate more R&D investment; however, the incentive of firms' seeking demand-side subsidies affects their allocation of private R&D expenditure (research activities or development activities), which results in lower level of basic research activities in terms of intangible assets investment.

Keywords

Purchase subsidies; Electric vehicles; R&D subsidies; R&D investment; Innovations

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1. Introduction

Electric vehicles (EVs hereafter) can reduce the demand for fossil fuels and they also have environmental and economic benefits (Shepherd *et al*., 2012). For this reason, widespread adoption of EVs becomes gradually popular throughout the world. In recent years, China's central and local governments have introduced a series of policies to promote the development of EV sector (Gong *et al*., 2012). With the support of huge fiscal subsidies, the market for EVs grows rapidly in China. Fundamentally, technological innovation is the key driving factor for sustained growth in the EV sector, which is of great importance for the upgrading of China's automobile manufacturing sector and enhancing China's competitiveness in the global electric vehicle market.

However, firms have incentives to under-invest in Research and Development (R&D) activities because private return for R&D is less than social return (Arrow, 1962; Duguet, 2004). It is a common practice to use public funding to subsidize private R&D projects (Görg and Strobl, 2007). Purchase subsidies[1] have often been used to support emerging industries (e.g., photovoltaic industry or EV sector), which is one of the important categories of government subsidies. In China, the subsidies for EVs are allocated based on output in most cases, and only those manufacturers producing the vehicles or their merchant companies (or customers in a few cases) are eligible for them. The thresholds for getting subsidies may not be well-designed enough to encourage more advanced technologies (e.g. technologies for longer driving range or lower recharging time of battery). Under some circumstances, the subsidies may even induce some distorted incentives. For instance, some speculative and fraudulent activities have ever been reported by media in the process of firms' seeking subsidies since 2015. It is therefore not clear whether the subsidies have been used to boost auto makers' R&D investment to improve their technologies for EVs production. Since government funding has become increasingly scarce particularly in times of a global depressing economy, it is very important that the limited funds can be targeted and used effectively (Becker, 2015). Considering the considerable amounts of public funding for EVs, evaluating the effects of subsidy policies is extremely important for policy makers. Moreover, considering that R&D subsidies are also an important and widely used form of government incentives for corporate innovation, a comparison of the impact of EV purchase subsidies with R&D subsidies on corporate R&D investments using comparable samples is of some theoretical and practical significance. For this purpose, this study is to investigate the impact of different categories of fiscal subsidies (R&D subsides or purchase subsides in the case of electric vehicles) on firms' private R&D investment among China's listed companies.

There are vast studies on EVs, which cover consumers' preferences towards adoption of EVs (e.g. Egbue and Long, 2012), factors affecting the demand for EVs (Shepherd *et al*., 2012), business model evolution for EVs' technologies (e.g. Bohnsack *et al*., 2014), optimal allocation of public charging stations for PHEVs (Wu, 2013) and so on. Meanwhile, there is a growing literature on government policies for EVs. Åhman (2006) studied Japan's policies for EVs and the development of this sector. Calef and Goble (2007) compared California's regulations and France's policies for EVs. There is also an increasing literature on the impact of subsidies for EVs in China, which have been investigated in terms of pollutant emission reduction (Zhang *et al*., 2020), financial performance (Wang *et al*., 2021), stock market reaction (Liu *et al*., 2022) and welfare consequences (e.g., Yang and Tang, 2019). As for its impact on EV adoption, Kalthaus and Sun (2021) found local government subsidies promoted EV diffusion in China and non-monetary

[1] Product subsidies are also used in related literature.

policies have a positive effect only for EVs.

However, there are relatively less studies on EV subsidy policy on firm innovation. Kulmer *et al*. (2022) discussed Austria's policies including subsidies and diffusion of low-carbon technologies (including EVs). Jiang *et al*. (2018) found that government R&D subsidies give rise to a crowding-in effect on NEV firms' R&D investment intensity. However, these two studies are either based on statistical data outside China or focusing on the impact of R&D subsidies on NEV firms. Jiang and Xu (2023) found that fiscal purchase subsidies for EVs had a significantly positive effect on innovation output, whereas they did not improve innovation efficiency of NEV manufacturers. Overall, further studies on this topic are still necessary.

The relationship between public funding and private R&D investment has been empirically investigated using different samples and estimation methods (see, for example, the survey on recent micro-econometric evidence by Z´uniga-Vicente *et al*., 2014). Earlier studies (e.g. Wallsten, 2000; Lach, 2002; González *et al*., 2005) provide much empirical evidence of the additionality effect of government R&D subsidies on private R&D as well as the substitution effect, whereas recent studies document more consistent evidence that public subsidies usually stimulate private R&D investment (Becker, 2015). However, most of these studies on this topic provide evidence from one of the developed countries (e.g. USA, UK, Canada, Austrilia or some European countries) or OECD countries as a whole, while there is relatively less evidence from developing countries. Howell (2017) studied the effects of China's public subsidies on innovation and productivity and found a crowding-in effect only in the sub-sample of high-tech industry. Boeing (2016) found a crowding-out effect of subsidies on innovation using the sample of China's listed companies. However, the dataset and the time periods for the data as well as the estimation methods for these two studies were totally different, and their findings were also not consistent. Hence, more studies on this topic are still necessary to provide more evidence from developing countries such as China.

Due to inconsistent conclusions about the relationship between public subsidies and private R&D investments, exploring this relationship by decomposing components of R&D or differentiating different sources of subsides is among the key issues deserving further study (Z´uniga-Vicente *et al*., 2014; Blanes and Busom, 2004). In view of these research suggestions, comparing the effects of different categories of subsidies should likewise be an interesting topic for further studies in this field. For instance, Clausen (2009) used the extent of distance to the market to distinguish research subsidies from development subsidies and found that the former stimulates private R&D activities and as a contrast, the latter may have a substitution effect on R&D. This study attempts to examine how different categories of subsidies affected innovation, which may contribute to extending the related studies in this relevant field.

A closer study on this is the one by Yu *et al*. (2016), which examined the impact of public subsidies on firms' R&D investment in the renewable energy sector and find a crowding-out effect of subsidies. However, their method may not consider the possible endogeneity between variables, and moreover, the role of China's government subsidies on innovation in the EVs sector remains unclear. Therefore, this study is aimed to fill this gap. To address the possible endogeneity problem, this study uses a propensity score matching method.

Using firm-level panel data on government subsidies and R&D investment, the study finds that China's subsidies for EVs have a significantly larger positive effect on R&D investment than R&D program subsidies for non-EVs in the matched sub-sample. And the results are robust when other measures for R&D investment are used. The author also investigates the pathways by which different categories of subsidies affected R&D. On the whole, the impact of subsidies for EVs on intangible assets is found to be significantly weaker than that of R&D project subsidies for non-EVs, whereas their effect on average wage is significantly more pronounced for EVs than for non-EVs. This indicates that subsidies for EVs stimulate R&D investment as a whole but the targeted expenditure direction on how to use the funds may be different and the level of research activities in terms of intangible assets is lower than that of its counterparts.

This paper differs from prior research and contributes to the existing related literature in three ways. Firstly, this study extends the literature on EV subsidy policy on firm innovation by providing some different empirical evidence from China. Secondly, this work differentiates between EV purchase subsidies and R&D subsidies and uses a different method (PSM method) to compare the impact of these two categories of subsidies. Besides, this study explores the underlying mechanism and the heterogenous effect of EV subsidies on R&D capitalization and R&D expensing, which sheds light on corporate accounting treatment of R&D expenditures and subsidies' effect on the real motivations of firm innovation.

The remainder of this paper is structured as follows. The second section introduces some backgrounds of China's purchase subsidy policies for EVs and proposes two hypotheses based on related theories and empirical evidence. The third section is about the empirical method of this study, and the fourth section presents the main results of the empirical analysis. The final section concludes with some suggestions for the EV sector.

2. Backgrounds and Theoretical Hypotheses

Introducing the backgrounds of China's purchase subsidies for EVs could provide some information on the importance of this category of subsidies and this subsection also serves as the basis of the following theoretical analysis.

2.1. China's purchase subsidy policies for EVs

The policies on subsidies for private EVs can be traced back to 2010. Prior to that, such support was only targeted towards vehicles for public service. In 2009, the Ministry of Finance (MOF) and Ministry of Science and Technology (MOST) launched a program for promoting the new energy vehicles and its demonstration in several cities by issuing the *Notice on Implementing the Pilot Program of Energy Savings and New Energy Vehicles* (MOF *et al*., 2009).

The *Notice of Launching Pilot Subsidies for Private Purchases of New Energy Automobiles* was issued on May 31, 2010 by the MOF, MOST, Ministry of Industry and Information Technology, and National Development and Reform Commission (MOF *et al*., 2010). And the regulations and measures for provisional support were also released at the same time. Specifically, plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) are the main support targets of the policy (Gong *et al*., 2012). According to this policy, subsidies were provided if the purchase or rent of vehicles, or the rent of batteries occurs. And the funds were granted to auto manufacturer in the first two cases and battery manufacturer in the latter case. Consumers buy EVs at a price, from which the amount of the subsidy for each vehicle was deducted. The products qualified for grants should be included in the official recommended list on some specific types of vehicles for support and the thresholds for the power of batteries subsidized were also required.

The amount of subsidy for each EV during the period of from 2010 to 2012 was determined based on its battery power, and the standard was set as 3,000 RMB per kwh with 50 thousand Yuan and 60 thousand Yuan at most for PHEVs and for BEVs respectively (MOF *et al*., 2010). It was also mentioned in the policy of 2010 that the subsidies at the central government level would decrease if the output of each firm separately for PHEVs and BEVs reaches 50 thousand.

In September 2013, China adjusted its subsidy program for EVs, which began to cover fuel cell vehicles (FCVs) as well. One change is that the subsidy for each EV in the period between 2013 and 2015 was determined based on driving range per charge for battery or the length of bus body (MOF *et al*., 2013).

In April 2015, China issued the subsidy program for the period between 2016 and 2020 for EVs and FCVs, which specified that the threshold of battery capacity of driving range for EVs to be subsidized should reach 100 km in 2016 (80km in previous years). The standard of subsidies for other types of vehicles also changed towards a higher level of requirements. And from 2017, the subsidies would be gradually cut at a rate of 20% every two years with the level of 2016 as the baseline (MOF *et al.*, 2015).

2.2. Theoretical hypotheses

R&D has some characteristics of public good and its positive external benefit is the reason of private under-investment in it (Almus and Czarnitzki, 2003). Public subsidies are thus used as a tool to provide some incentives of R&D investment for firms. In theory, the subsidy policy grants could not only allow recipients to directly conduct the innovation input activities, such as the R&D investment, but could also cover some expenditures to register their own patents or purchase some patents from other firms (Bronzini and Piselli, 2016), which might include some standard essential patents that are the basis for their subsequent technology innovation. When technology spillovers were low, output subsidies (or purchase subsidies) were superior to R&D subsidies and could lead to higher social welfare (Lee *et al*., 2017). There is also some empirical evidence from European countries that subsidized firms tend to produce more innovation output compared with their counterparts (Alecke *et al*., 2012; Bronzini and Piselli, 2016). Based on the abovementioned analysis, the innovation effect of purchase subsidies for EVs can be predicted in China. Therefore, the following hypothesis is proposed.

Hypothsis 1: the impact of EV subsidies on R&D investment is positive.

Some explanations and predictions about the underlying mechanism why there are some differences in the effects on firm innovation between purchase subsidies EVs and R&D subsidies for non-EVs are provided in this part.

The two major components of R&D, research and development, are very different with various purposes (Barge-Gil and Lopez, 2014). Specifically, research is more characteristic of uncertainty and intangibility than development, and meanwhile social returns from research activities are larger than those from development activities (Z´uniga-Vicente *et al*., 2014). Therefore, research spending is more seriously under-invested due to financing constraints (Czarnitzki *et al*., 2011). For this reason, theoretically, R&D subsidies for research projects are more targeted and more concerned about the involved projects' outcome and innovation, compared with purchase subsides. Therefore, they should be more effective in stimulating basic research investments. Empirical evidence (e.g. Clausen, 2009) also supports this view. Clausen (2009) distinguished two kinds of subsidies (i.e "far from the market" subsidies and "close to the market" subsidies) and he also found that the former kind of subsidies has a positive effect on research activities while the latter kind has no such effect. For this study, purchase subsidies for EVs are more similar to the "close to the market" subsidies whereas R&D program subsidies for non-EVs are more similar to the "far from the market" subsidies. Furthermore, the market structure is different across sectors along the supply chain of the automobile industry. Automobile parts, engine and battery manufacturing enterprises in the upstream are subject to more intensive competition and farther from the final product market, while the vehicle manufacturing firms are nearer to the final product market and own greater market power. Firms in the downstream enjoy the expected duration of monopoly power due to creative destruction (Akcigit *et al*., 2020). When the downstream firms (vehicle manufacturers) are granted demand-side purchase subsidies, they are less likely to invest in basic research and radial innovation than their counterparts in the upstream based on above mentioned theoretical and empirical findings. According to Bronzini and Iachini (2014), intangible investment can be regarded as not only one of the important research expenditures but also the final purpose for research activities. It can be expected that subsidies for EVs will have less pronounced effect on intangibles than R&D subsides. Based on the technology-skill complementarity theory, R&D investment will increase the demand for skilled workers, which result in the increase in average wage (Mishra and Smyth, 2014). Therefore, if the EV subsides' overall effect on R&D expenditure is larger than R&D subsidies' effect, their effect on labor cost should be more pronounced. Hence, the author proposes the following hypotheses.

Hypothesis 2: the impact of EV subsidies on intangibles is expected to be significantly weaker than that of R&D subsidies whereas their impact on labor cost is more pronounced than the latter.

3. Methods

3.1. Data source and variables

The author uses the data of listed companies in Wind's database for financial information, which are collected from companies' annual financial reports. For the purpose of matching, the original data is comprised of both the EV and the non-EV sectors. Since the subsidies for EVs had been reduced gradually since 2018, the data for this study is collected from 2011 until 2016. Companies from the financial sector are excluded when choosing the sample. Totally 4 abnormal observations were deleted when the subsidies, R&D expenditure-capital expenditure or the ratio of assets to liability is smaller than zero.

According to prior related studies (e.g. Becker, 2015), input measures and output measures for R&D are both used as outcomes. Input measures include R&D intensity, the ratio of R&D expenditures to sales. Other input measures of R&D, the natural log of expensed R&D expenditures and the natural log of capitalized R&D expenditures, are also used as outcome variables for a robust test. Output measures include intangibles. The dummy variable "wauto", the one period lag of the natural log of government subsidies and the interaction item between these two variables are the variables of interest. The variable "wauto" denotes whether a company is granted subsidies for EVs and is used as the proxy for the treatment variable, which equals to 1 if a company produces the EVs as a final product, and 0 otherwise. The author uses the natural log of subsidies as one independent variable, and assesses the impact of public funds by comparing R&D investments between EV companies and comparable companies from other sectors. Lach (2002) found that the effect of public subsidies occurs with one-year lag, which is the reason for the use of the one year lagged value of subsidies in this study. The control variables include firm size (lntass or lnemp), leverage ratio (lev), tax burden (tax) and average salaries for employees (lnwage)[2], which have been used by previous related literature (e.g. Agrawal *et al*., 2020; Buyse *et al*., 2020; Zhao *et al*., 2023) and are regarded to be associated with firms' investment in innovation activities.

Due to the characteristic of the available data, this study is partially different from those using data of R&D program application from developed countries, most of which compare the outcomes in R&D between the recipients of subsidies and non-recipients without subsidies. This study turns to compare the effect of EV subsidies and that of non-EV subsidies for other sectors, which is similar to Dick and

[2] The definitions of control variables are presented in Table 1.

Wang (2010) who intended to find the impact of Olympic events by assessing the abnormal returns after the announcement of the events against a usual situation (instead of comparing the difference between winners and losers). The other sectors are used to obtain the comparison group. Although the companies in other sectors of this study do not get the subsidies for EVs, they get other kinds of R&D funds for respective specific sectors. The subsidies for EVs are particular and different from subsidies for R&D programs in that the former is market-oriented and the latter is R&D project oriented; the total amounts of EV subsidies are substantial and assigned based on each company's output of EVs before 2017, and to some extent they are easier to apply due to the low thresholds of technology requirements for the subsidies as well. Moreover, because of the particularity of subsidies for EVs, a number of companies have been reported to be involved into fraud, which is less obvious in other sectors.

Descriptive statistics of several relevant variables for this study are summarized in Table 1. As can be seen, the number of non-missing observations for R&D investment is about one third of the valid observations for most of the control variables. Corporate incomes for different sectors are all subject to a tax rate of 25% in most cases, whereas they can be deducted and levied at a lower rate if the sector or the main business of a company is of great importance to the development of the nation (e.g. 15% for the high-tech companies).

Table 1
Summary statistics of the variables.

Variable	Meaning	Observations	Mean	SD
rd	R&D investment (million)	7570	139.70	561.50
sub	Public subsidies (millions)	17778	31.57	137.28
exp	R&D expenditure- Expense (million)	6662	132.22	566.71
cap	R&D expenditure-Capital expenditure (million)	2367	43.13	138.20
tax	Income tax rates	18504	18.67	5.35
lev	Leverage; The ratio of assets to liability	19919	44.88	47.59
lntass	The natural log of total assets	19924	21.69	1.59
lnemp	The natural log of the number of employees	19692	7.40	1.37
lnintas	The natural log of intangibles	19519	18.03	2.01
lninc	The natural log of revenue	19916	21.04	1.57
lnfa	The natural log of tangible assets	19914	19.68	1.92
lnwage	The natural log of average salaries	19722	16.59	1.84

The treated units from the EV sector may be very different from untreated units from other sectors as a whole. A direct comparison of the impact of subsidies between EVs and Non-EVs may lead to estimation bias. In this case, choosing an appropriate matching method is necessary. The aim of matching is to choose a subset of untreated units as a comparable group whose observable characteristics can more closely resemble the treated group (Dehejia and Wahba, 2002). In particular, the propensity score matching (PSM) methodology balances characteristic distributions of observed covariates between a treatment and a control group (Mendola, 2007). The matched pairs are chosen on the basis of similarities in the characteristics of observables (Jalan and Ravallion, 2003). Since the main purpose of the propensity score estimation is to balance all covariates but not to predict selection into treatment as well as possible (Augurzky and Schmidt, 2001), this allows the author to use the method for his study.

3.2. Empirical strategies

Typically, PSM methodology follows the following procedure. The first step of this method is to choose the variables that influence the probability of being the treated group. After the matching estimation, balancing tests are conducted (List *et al*., 2002). If the significant differences between the groups for comparison before matching are not significant anymore after matching, then unmatched observations are discarded out of the sample and a matched sub-sample is left and used for later comparison and analysis. To implement the matching technique, the treatment group in this study is defined as the set of companies producing the final products of EVs. A logit model and the nearest-neighbor matching method are adopted for the first step of the PSM evaluation in this study.

Nearest neighbor matching (NNM) is regarded as the most straightforward matching algorithm and the rationale behind this method is that a treated firm's matching partner is chosen from the control group and determined by means of closest propensity score (Caliendo and Kopeinig, 2008). In addition, alternative matching approaches such as radius matching and kernel matching (KM) have also been tried. Subsequent analysis is based on the matched sample obtained by using more to one NN matching method. The reasons are as follows. Most of the covariates are imbalanced after using other matching methods. Besides, Caliendo and Kopeinig (2008) held that when there are a large number of comparable untreated firms, the "more than one NN matching"[3] (or KM) is suggested to get more precise estimates. Since the control sample in this study is large enough, a "m-to-l" matching with m > 1 can be adopted to reduce the standard errors (Jalan and Ravallion, 2003). Therefore, the "m" in this study is 3. According to Duguet (2004)'s reasons for selection of the attributes, the author determines 6 variables for the logit model, including lnfa, lnemp, lnwage, tax, lev and lnpresub. Economic theory and prior related research are the basis for selecting matching variables, which should affect both the treatment variable and the outcome (Smith and Todd, 2005; Caliendo and Kopeinig, 2008). Based on these principles, firm size[4] (lnemp), tax rates (tax), tangible assets and leverage ratio (lev) are determined as matching variables according to Agrawal *et al*., (2020) and Zhao *et al*., (2023). There is also some empirical evidence of the positive relationship between employment and subsidies (e.g. Branstetter *et al*., 2023), both the number of employees (lnemp) and average salaries (lnwage) are therefore included in the matching covariates of this study. The variable "lnpresub" is associated with current year's subsidy but not affected by it, and thus is also included in the model. A further evaluation of the impact of EV subsidies is conducted after obtaining the matched sub-sample.

The regression model as follows is used for further evaluation.

$$RD_{it}=\ln presub_{it}+wauto_{it}+\ln presub_{it}\times wauto_{it}+\sum Z_{it}+\varepsilon_{it} \quad (1)$$

Where RD_{it} denotes the measures of R&D investment, $\ln presub_{it}$ denotes the lagged value of the natural log of government subsidies, $wauto_{it}$ is a dummy variable with 1 representing the companies producing the final product of EVs and 0 otherwise, $\ln presub_{it}\times wauto_{it}$ is the interaction item between the previous two variables, ε_{it} is error item, and $\sum Z_{it}$ represents different sets of control variables, which include lntass, lnemp, lnwage, tax and lev. Robust standard errors are used.

The study also explores the pathways that the subsidies affected R&D by the following model.

$$Y_{it}=\ln presub_{it}+wauto_{it}+\ln presub_{it}\times wauto_{it}+\sum Z_{it}+\varepsilon_{it} \quad (2)$$

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[3] This is also named as "m to 1" nearest neighbor matching or K nearest neighbor matching.

[4] The number of employees is sometimes used to define firm size by some scholars or research report such as the Census Statistics on Small Businesses (Denes *et al*., 2019). And only one indicator for firm size is used according to Caliendo and Kopeinig, (2008) and thus the total asset (lntass) was not included here.

Where Y_{it} denotes the measures of outcomes which indicate the R&D outlays and further the mechanism that the EV subsidies affect R&D investment. Due to unavailability of the data for direct R&D investment, the items on the balance sheets that are allowed to be as R&D outlays and reimbursable by the program are used as outcome variables in Bronzini and Iachini (2014). To be specific, tangible and intangible investments are the main reimbursable outlays in their study. And other reimbursable outlays include those items related to the employment of researchers (e.g. labor costs and level of employment). Hence, following Bronzini and Iachini (2014) with consideration given to China's practice, Y_{it} in model (2) includes the natural log of intangible assets, administrative expenses and average wage.

4. Results

The study first uses a propensity score matching method to estimate the impact of the public subsidies for the EV sector on firms' R&D investment. It also uses several different measures of the outcome to conduct a robustness test. Then it explores the potential pathways by which the government subsidies may affect the outcome for R&D investment.

The first-stage estimation of the PSM method is conducted by a logit regression model. Results of logit estimation of the propensity score are reported in Table 2. The results suggest that compared with those in other sectors, the companies in the EV sector are more likely to have more employees and less fixed assets. They are more likely to afford higher average wage to employees. The model also predicts that they may be more probably to keep a higher financial leverage and get more one-period lagged subsidies.

Table 2
Logit estimation of the propensity score.

Variable	Wauto
lnfa	-0.425***
	(0.115)
lnemp	0.612***
	(0.199)
lnwage	0.218*
	(0.127)
tax	-0.029
	(0.026)
lev	0.029***
	(0.006)
lnpresub	0.583***
	(0.122)
Constant	-15.740***
	(1.908)
Observations	7,088
Pseudo R-squared	0.251

Note: standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The first row of Table 3 presents the means of the outcome variable (R&D investment) for the treated and the control group and also their difference and t-statistic in the unmatched sample; and the second row reports the same statistics after matching. The t-statistics is 19.060 and 0.570, which indicate that the difference between the two groups is statistically significant before matching and not yet significant after matching.

Table 3
Means for the treated and control group and their difference.

Variable	Sample	Treated	Controls	Difference	S.E.	t-stat
Rd(million)	unmatched	1352.761	131.023	1221.738	64.100	19.060
	ATT	1124.358	984.295	140.063	244.251	0.570

The means of covariates in the unmatched and matched sample for the treated and the controls before and after matching are presented in Table 4. For all six variables, as can be seen, there are no significant differences in the means at the 1% significant level and none of the covariates systematically fails the mean equality test after matching, although this is not true before matching.

Table 4
Means of covariates for the treated and control group before and after matching.

		Mean			
Variable	**Unmatched / Matched**	**Treated**	**Control**	**t**	**p>|t|**
lnpresub	Unmatched	18.350	15.870	12.830	0.000
	Matched	18.230	18.270	-0.130	0.897
lnemp	Unmatched	9.623	7.561	13.510	0.000
	Matched	9.545	9.492	0.220	0.826
lnwage	Unmatched	19.430	16.830	12.790	0.000
	Matched	19.320	19.260	0.170	0.865
lnfa	Unmatched	22.020	19.930	9.740	0.000
	Matched	21.940	21.880	0.160	0.871
lev	Unmatched	62.570	39.460	9.280	0.000
	Matched	62.670	62.580	0.030	0.974
tax	Unmatched	19.760	17.390	3.870	0.000
	Matched	19.920	20.140	-0.230	0.817

Using a sub-sample of the matched observations as the new sample and the proportion of R&D expenditures to sales as the outcomes, parametric estimates of equation (1) are conducted to compare subsidies for EVs and subsidies for non-EV R&D subsidies in their effects on R&D investment. Results with only one control variable are reported in Table 5, column (1). And the estimates are replicated using a different set of control variables, which are presented in columns (2)–(4) and the year effect is additionally controlled for column (5). Although the coefficient on lnpresub is not significant on the whole, the natural log of one-period lagged subsidies for the EV sector are positively associated with lnrdp at least at the 5%

significance level, which indicates that subsidies on the EVs sector stimulate R&D investment compared with the matched group. Hypothesis 1a is supported in the sub-sample of the EV sector.

Table 5
Parametric estimates of the effect of subsidies using the matched sub-sample.

Variable	(1) lnrdp	(2) lnrdp	(3) lnrdp	(4) lnrdp	(5) lnrdp
lnpresub	0.077	0.074	0.096	0.080	0.082
	(0.077)	(0.076)	(0.075)	(0.072)	(0.074)
wauto	-0.819**	-0.520	-0.641	-0.319	-0.320
	(0.352)	(0.393)	(0.433)	(0.465)	(0.464)
wauto×lnpresub	0.087***	0.070***	0.079***	0.061**	0.061**
	(0.020)	(0.022)	(0.024)	(0.026)	(0.026)
lntass	-0.307***	-0.253***	-0.140	-0.084	-0.085
	(0.095)	(0.095)	(0.177)	(0.177)	(0.182)
lev		-0.016***	-0.016***	-0.014***	-0.014***
		(0.005)	(0.005)	(0.005)	(0.005)
lnemp			-0.019	-0.002	-0.004
			(0.188)	(0.178)	(0.186)
lnwage			-0.131	-0.143*	-0.143*
			(0.086)	(0.084)	(0.085)
tax				-0.041*	-0.041*
				(0.023)	(0.023)
Constant	6.307***	6.048***	5.648**	5.326**	5.285**
	(1.606)	(1.570)	(2.531)	(2.439)	(2.506)
Year effect					Yes
Observations	226	226	226	226	226
R-squared	0.150	0.190	0.198	0.219	0.219

*Note: robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$*

Table 6 presents the regression results for the effects of subsides using other different measures of R&D investment separately. Column (1) of Table 6 shows that the effect of subsidies for EVs in the previous year on administrative expenses is significantly more pronounced than that of subsidies for R&D project in other sectors. The estimates with lnexp as the outcome variable are presented in columns (2) and (3) and are also replicated using lncap as the outcome for columns (4) and (5). Results show that lnpresub is positively significantly related to both measures for R&D expenditure, and the coefficient on the interaction item is also significantly positive. These findings suggest that the impact of EV subsidies and that of non-EV R&D subsidies are significantly positive for EVs and for non-EVs, respectively, and further, the impact of the former is more pronounced. However, the coefficient on wauto is significantly negative, which indicates that the R&D capitalized expenditure for EV producers is lower than their comparable counterparts.

Table 6
Effects of subsidies on R&D investment using the matched sub-sample.

Variable	(1) lnadexp	(2) lnexp	(3) lnexp	(4) lncap	(5) lncap
lnpresub	0.085**	0.244***	0.248**	0.567***	0.542***
	(0.041)	(0.092)	(0.099)	(0.188)	(0.190)
wauto	-0.742***	-0.618	-0.589	-3.055***	-3.120***
	(0.206)	(0.419)	(0.426)	(0.639)	(0.806)
wauto×lnpresub	0.041***	0.082***	0.082***	0.266***	0.269***
	(0.012)	(0.024)	(0.024)	(0.038)	(0.046)
lnfa	0.104**	0.404***	0.394***	-0.047	-0.004
	(0.049)	(0.094)	(0.099)	(0.197)	(0.203)
lev	0.002	-0.005	-0.005	-0.022**	-0.020**
	(0.003)	(0.007)	(0.007)	(0.010)	(0.010)
tax	-0.001	-0.031	-0.030	0.021	0.015
	(0.010)	(0.026)	(0.026)	(0.048)	(0.047)
Constant	9.378***	6.574***	6.401***	8.788***	8.682***
	(0.635)	(1.551)	(1.613)	(2.690)	(2.720)
lnemp	0.778***				
	(0.070)				
Year effect			Yes		Yes
Observations	227	206	206	91	91
R-squared	0.816	0.366	0.371	0.464	0.473

Effects of subsidies on R&D investment using the matched sub-sample.The pathways underlying the effect of subsidies on firm's innovation are investigated here. The regression results in column (1) of Table 7 show that the impact of subsidies for EVs on intangible assets is significantly weaker than that for the comparable sample, while results in the other column of Table 7 show that the effect on average wage is significantly more pronounced for EVs than for non-EVs, which indicates that subsidies for EVs stimulate R&D investment but the targeted investment direction may be different; and further the level of R&D in terms of intangible assets is still lower than its comparable counterparts.

Table 7
Exploring how different kinds of subsidies affect R&D.

Variable	(1) lnintas	(2) lnwage
lnpresub	0.119*	0.105*
	(0.069)	(0.058)
wauto	0.311	-1.306***

Table 7. (continued)

Variable	(1) lnintas	(2) lnwage
	(0.233)	(0.316)
wauto×lnpresub	-0.024*	0.071***
	(0.013)	(0.017)
lnfa	0.479***	0.032
	(0.073)	(0.078)
lnemp	0.527***	0.918***
	(0.094)	(0.091)
lev	-0.003	0.006**
	(0.003)	(0.003)
tax	0.016	0.004
	(0.012)	(0.014)
Constant	2.667***	7.411***
	(0.948)	(0.879)
Observations	225	227
R-squared	0.802	0.719

*Note: robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

5. Conclusions

Using firm-level panel data on government subsidies and R&D investment, the study first uses a propensity score matching method to obtain a matched sub-sample for further analysis of the impact of different kinds of subsidies. Then the author conducts a parametric estimation within the matched sub-sample and finds that subsidies for EVs have a significantly more positive effect on R&D investment than subsidies for R&D programs in the non-EV sector. And the results are robust when other measures for R&D investment are used. The study also investigates how different categories of subsidies affected innovation. On the whole, the impact of subsidies for EVs on intangible assets is found to be significantly weaker than that for the comparable group while the effect on labor cost is significantly more pronounced for EVs than for Non-EVs. This indicates that although subsidies for EVs stimulate R&D investment as a whole, purchase subsides affect the allocation of private R&D expenditure between basic research activities and development activities, which further result in lower level of basic research activities and hamper firms' innovation in terms of intangible assets investment.

The findings of this research have both theoretical meaning and practical value. On the one hand, this study extends the subsidy and innovation literature by providing some theoretical analysis of both the relationship and its underlying mechanism and some corresponding empirical evidence from different perspectives, which is conducive to a better and profound understanding of this research field. On the other hand, the findings of EV purchase subsidies effect vis-à-vis R&D subsidies effect have also some important implications to the design of subsidy policy according to different industrial and sector features.

There exist some limitations of this study. For instance, the selection of matching variables can be improved by using more sources of data on information of technological aspects to replace the present ones. The dataset used covers the data from 2011 to 2016, and some data for R&D expenditures start from 2014, which constrains the use of more appropriate methods in this study. Future studies may overcome this issue with more advanced methods or may extend this literature by more careful and in-depth analyses of subsidies.

Despite some new exploratory findings of this study, future research is still necessary and of great significance to investigate the relationship between different sources of subsidies and different types of R&D activities including basic research, and applied one when more related data are available. Some additional methods, such as the PSM-DID or IV method can be used in subsequent studies to identify a causal relationship, if possible.

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