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The Impact of Purchase Subsidy on Enterprises' R&D Efforts: Evidence from China's New Energy Vehicle Industry

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Received: 11 December 2019; Accepted: 21 January 2020; Published: 4 February 2020



Abstract: Purchase subsidy has been adopted to accelerate the diffusion of New Energy Vehicles (NEVs) in China. With a Multi-stage Difference-in-Differences (DID) method, this research investigates the impact of purchase subsidy on Research and Development (R&D) efforts of NEV enterprises. The results indicate that purchase subsidy for NEVs has a positive and significant impact on R&D efforts of NEV enterprises. The impact increases when the purchase subsidy rate decreases. When considering the influences of government procurement and exemption on purchase tax, the positive impact of purchase subsidy still remains significant. The policy implications are that the purchase subsidy rate should be reduced, and stricter technological requirements should be set to couple with the purchase subsidy.

Keywords: NEV enterprises; R&D efforts; purchase subsidy

1. Introduction

With the deterioration of the environment and ecology, the synergetic relationship of economic growth and environmental protection is attracting increasing attention in China [1,2]. New energy vehicles (NEVs) are of great importance for China to decouple the conflicts between economic growth and environmental protection. However, as the knowledge creation and environmental benefits cannot be fully reflected in market prices [3,4], the innovation of NEV enterprises may suffer from the so-called 'double externality problems.' As a result, China's NEV enterprises may underinvest in R&D activities, and cannot gain technological competence in the international market. Thus, governmental subsidies are essential to compensate for the underinvestment [5,6].

Demand incentives have been used to stimulate enterprises' innovation through creating niche markets and generating higher returns for enterprises in emerging industries [7]. In 2008, the "Circular of Guideline of Government Procurement" was implemented in China to launch the public demand for NEVs. To launch the private demand, purchase subsidy was announced in the "Notice on Launching Pilot Projects of Subsidy for Private Sales on New Energy Vehicles" in 2010. In this notice, Shanghai, Changchun, Shenzhen, Hangzhou, and Hefei were selected as pilot cities for the adoption of NEVs. To cope with the increasing seriousness of air pollution, large cities in the Yangtze River Delta Region, Pearl River Delta, and Beijing–Tianjin–Hebei Delta were added as pilot cities in the "Notice on Promotion and Adoption of New Energy Vehicles" in 2013. In 2014, technological requirements matched with purchase subsidy were put forward in the "Notice on Further Promotion and Adoption of New Energy Vehicles," and the subsidy rates were decreased accordingly. To offset the decrease of purchase subsidy rates, an exemption of purchase tax on NEVs was announced in the "Notice on



the Exemption of Purchase Tax on New Energy Vehicles" in 2014 and "Announcement on Exemption of Purchase Tax on New Energy Vehicles" in 2017. The demand incentives for NEVs in China are presented in Table 1.

Туре	Year	Policy Name	Department	Key Criterion
Purchase Subsidy	2010	Notice on Launching Pilot Projects of Subsidy for Private Sales on NEVs	MOF, MST, MIIT, NDRC	Purchase subsidy ≤ 50,000 RMB Per BEV Purchase subsidy ≤ 6000 RMB Per Plug in Hybrid Electric Vehicle (PHEV)
	2013	Notice on Promotion and Adoption of NEVs	MOF, MST, MIIT, NDRC	Purchase subsidy \leq 60,000 RMB Per BEV Purchase subsidy \leq 35,000 RMB Per BEV Purchase subsidy \leq 200,000 RMB Per BEV
	2014	Notice on Further Promotion and Adoption of NEVs	MOF	Purchase subsidy in 2014 and 2015 is decreased by 5% and 10% to 2013.
	2015	Notice on Financial Support on Promotion and Adoption of NEVs from 2016 to 2020	MOF	Purchase subsidy from 2017 to 2018 is decreased by 20% to 2016. Purchase subsidy from 2019 to 2020 is decreased by 40% to 2016.
	2016	Notice on Adjustment of Financial Support on Promotion and Adoption of NEVs	MOF, MST, MIIT, NDRC	Purchase subsidy is adjusted in accordance with the energy consumption, mileage, battery, and safety of NEVs.
Government Procurement	2008	Circular of Guideline of Government Procurement	MOF	Launch government procurement on NEVs.
	2014	Notice on Purchase Program for NEVs for Government Departments and Public Institutions	NGOA, MOF, MST, MIIT, NDRC	Volumes of government procurement on NEVs \geq 30%.
Tax - Exemption	2014	Notice on the Exemption of Purchase Tax on NEVs	MOF, DTP, MIIT	Tax exemption for NEVs was carried out from 2014 to 2017.
	2017	Announcement on Exemption of Purchase Tax on NEVs	MOF, DTP, MIIT, MST	Tax exemption for NEVs was carried out from 2018 to 2020.

Table 1. Demand	incentives	for NEVs	in China.
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Note: MOF denotes Ministry of Finance; DTP denotes The Department of Tax Policy; MIIT denotes Ministry of Industry and Information Technology; MST denotes Ministry of Science and Technology; NDRC denotes National Development and Reform Commission; NGOA denotes National Government Offices Administration; NEV denotes new energy vehicle; BEV denotes battery electric vehicle.

As a key policy instrument to promote the demand for NEVs in China, purchase subsidy has triggered a massive growth in the production of NEVs. However, a generous subsidy may incentivize NEV enterprises to capture benefits from economies of scale through learning by doing, and raise the likelihood of technological lock-ins. To address this question, this study investigates the impact of purchase subsidy on the R&D efforts of NEV enterprises with the Multi-stage Difference-in-Differences (DID) method.

The other parts of this paper are organized as follows: Section 2 provides an overview of the relevant literatures. Section 3 introduces research methods and data resources. The estimation results are presented in Section 4. Section 5 provides conclusions and policy implications.

2. Literature Review

The market creates substantial benefits for enterprises R&D efforts. Many researches have investigated the impact of demand on enterprises' innovation. With the case of mobile communication enterprises, Corrocher et al. [8] found that demand growth has stimulated enterprises' innovation in Italy. Lin et al. [9] found that demand growth promotes motorcycle enterprises' green innovation in Vietnam. In Spain, the decrease of demand causes the decrease of innovation investments in manufacturing enterprises [10]. In China, Li et al. [11] found that market-oriented measures have

promoted energy technology innovation, and Gao et al. [12] found that local demands promote the innovation of the photovoltaic (PV) industry. However, Wang et al. [13] found that demand cannot promote the innovation of the Chinese wind power industry. Because consumers can provide useful information in product and service innovation, the degree of enterprises' technological innovation may also be influenced by demand heterogeneity [14–16].

Demand-side incentives may create niche markets and accelerate the adoption of NEVs. Diamond [17] found that purchase subsidy for NEVs in the USA has accelerated the adoption of electric vehicles. In China, Ma et al. [18] found that purchase subsidy has promoted the adoption of NEVs. In the UK, perfect price signals and a consumer-led approach are identified as necessary for the adoption of electric vehicles [19]. Combing the Cournot model and Stackelberg model, Yang et al. [20] found that subsidies provided to consumers may bring out higher social welfare than those provided to NEV enterprises. Of all demand-side incentives, Bjerkan et al. [21] found that the price-reduction policy is the most powerful in promoting the adoption of electric vehicles.

Demand-side incentives may enhance the return of innovation investment in emerging markets. Several researches have investigated the impact of demand-side incentives on the innovation of NEV enterprises. In China, Chen et al. [22] found that the mixed use of demand-side incentives have stimulated the innovation activities of NEV enterprises. Zhao et al. [23] found that the demonstration project named "1000 Vehicles in 10 cities" has increased the amount of invention patent in NEV enterprises. Using the dynamic panel model, He et al. [24] found that purchase subsidy on NEVs has promoted patent applications in NEV enterprises.

The above literatures indicate that demand acts as a key role in enterprises' innovation, and demand-side incentives may correct enterprises' innovation externalities to some degree. Therefore, we expect that:

Hypothesis (H1): The purchase subsidy has a positive effect on NEV enterprises' R&D efforts.

However, a rapidly growing market may decrease enterprises' R&D investment in new technologies, and raise the likelihood of technological lock-ins. With global samples, Hoppmann [25] found that enterprises producing solar photovoltaic (PV) modules have shifted from exploration to exploitation on account of the rapidly growing market. In the US, Nemet [26] found that strong market growth induces enterprises of wind turbines to pursue mature technologies, and decrease the investment in exploring new technologies. Thus, a generous subsidy may decrease NEV enterprises' R&D efforts in China. We hypothesize that:

Hypothesis (H2): The decrease of purchase subsidy rate promotes NEV enterprises' R&D efforts.

3. Model Specification and Data

Government policies for NEVs in China are shifting from producer-rientation to consumerorientation [27]. Purchase subsidy may accelerate the adoption of NEVs, and stimulate enterprises' R&D efforts by expanding innovation demand [28]. In practice, NEV enterprises may gain access to purchase subsidy when the vehicle models are qualified in the recommended catalogue from the Ministry of Industry and Information Technology (MIIT). We selected 52 listed enterprises that included NEVs manufacturing as research samples. For the data availability, 46 NEV enterprises were used to investigate the impact of purchase subsidy. The purchase subsidy has been implemented since 2010, NEV enterprises with vehicle models qualified in the recommended catalogue were assigned into a treated group, and those without vehicle models qualified in the recommended catalogue were assigned into control group. By comparing the treated group and control group with a quasi-experimental method, the impact of purchase subsidy on R&D efforts of NEV enterprises may be estimated. Using the Multi-stage DID method, the average treated effect of the purchase subsidy can be estimated with Equation (1).

$$R\&D_{it} = \beta_0 + \beta_1 du \times dt_{it} + \theta_1 Sub_{it} + \theta_2 Size_{it} + \theta_3 Lev_{it} + \theta_4 Age_{it} + \theta_5 Profit_{it} + \varepsilon_{it}$$
(1)

As some NEV enterprises defrauded purchase subsidy with inflated sale volume, China began to cut down the purchase subsidy rate for NEVs since 2014. The decrease of the purchase subsidy rate may influence R&D efforts of NEV enterprises [29]. To address this question, *Exit* is used to denote the decrease of purchase subsidy rate. The effect of purchase subsidy on the R&D efforts of NEV enterprises can be estimated with Equation (2).

$$R\&D_{it} = \beta_0 + \beta_1 du \times dt_{it} \times Exit_{it} + \theta_1 Sub_{it} + \theta_2 Size_{it} + \theta_3 Lev_{it} + \theta_4 Age_{it} + \theta_5 Profit_{it} + \varepsilon_{it}$$
(2)

Here, $R\&D_{it}$ is the independent variable. $R\&D_{it}$ denotes R&D efforts of NEV enterprises, and is measured by the ratio of total R&D investment to the total asset [30].

" $du \times dt$ " is the treatment variable. du takes value 1 if NEV enterprises gain purchase subsidy, and 0 otherwise. dt takes value 1 in the years NEV enterprises gain purchase subsidy, and 0 otherwise.

Five variables are used to control the characteristics of NEV enterprises. *Sub* denotes the subsidy amount that NEV enterprises received from the government [31]. Large enterprises may undertake R&D risks, and spread R&D costs to large-scale productions. Here, *Size* denotes NEV enterprises' scale, and is measured by the total assets [32]. Enterprises' R&D efforts may be influenced by the financial risks of NEV enterprises. Here, *Lev* denotes the financial risks of NEV enterprises, and is measured by the ratio of total debt to the total asset [33]. Enterprises' age is associated with the level of managerial capacities and experiences, and may affect enterprises' R&D efforts. Here, *Age* is used to denote enterprises' age, and is measured by the years from registration [34,35]. Profit may provide favorable substantial conditions for enterprises' R&D efforts. *Profit* is used to denote enterprises' profit, and is measured by the ratio of total profit to total profit to total income.

From the period of 2008 to 2017, government procurement and exemption on purchase tax were used as important instruments to promote the adoption of NEVs. The impact of purchase subsidy on the R&D efforts of NEV enterprises may be influenced by these two instruments. The influences of government procurement and exemption on purchase tax are introduced in Equation (3).

$$R\&D_{it} = \beta_0 + \beta_1 du \times dt_{it} + \beta_2 Proc_{it} + \beta_3 Exemp_{it} + \theta_1 Sub_{it} + \theta_2 Size_{it} + \theta_3 Lev_{it} + \theta_4 Age_{it} + \theta_5 Profit_{it} + \varepsilon_{it}$$
(3)

"Proc" denotes government procurement. If NEV enterprises' vehicle models are qualified in the government procurement list, the variable "Proc" is taken as 1, and 0 otherwise. "Exemp" denotes exemption on purchase tax. If NEV enterprises' vehicle models are qualified in the catalogue of exemption on purchase tax, the variable "Exemp" is taken as 1, and 0 otherwise.

The definitions of main variables are listed in Table 2.

Variables	Definitions
R&D	The ratio of total R&D investment to total asset of NEV enterprises (%)
$du \times dt$	Equal to 1 if NEV enterprises gain purchase subsidy, and 0 otherwise.
Sub	The amount of subsidies that NEV enterprises received from government (10,000 RMB)
Size	The amount of NEV enterprises' total assets (10,000 RMB)
Lev	The ratio of total debt to total asset of NEV enterprises (%)
Age	The years from registration (Year)
Profit	The ratio of total profit to total income of NEV enterprises (%)

Forty-six listed NEV enterprises with 428 observations were used to estimate the impact of purchase subsidy on R&D efforts of NEV enterprises. Research samples with vehicle models qualified in the recommended catalogue were selected in the "Catalogue of Recommended Models for Demonstration

and Application of Energy Saving and New Energy Vehicle" (2010–2017). The data of *R&D*, *Sub*, *Size*, *Lev*, *Age* and *Profit* were collected in the China Stock Market and Accounting Research Database (CSMAR). The data of *Proc* were collected from the Chinese government procurement website, and the data of *Exemp* were collected from the "Catalogue of models of New Energy Vehicles Exempted of Purchase Tax" (2014–2017).

Prices in variables were eliminated to 1978 (China's economic reform began in 1978; the prices are usually deflated to 1978 in related researches), and the absolute values are taken logarithm to eliminate multiple colinearity. The mean, standard deviation, minimum, and maximum of variables are given in Table 3.

Variable	Mean	Std. Dev	Min	Max
R&D	0.024	0.026	0.000	0.399
Sub	15.321	3.021	0.000	20.040
Size	17.119	4.354	9.592	24.779
Lev	0.554	0.176	0.072	0.970
Age	2.660	0.500	0.000	4.060
Profit	0.059	0.254	-2.207	3.107

Table 3. Descriptive Statistics.

4. Results

4.1. DID Estimation

A Multi-stage DID method is used to estimate the impact of purchase subsidy on the R&D efforts of NEV enterprises. Figure 1 provides the parallel trends of research samples, which shows a sudden rise of R&D efforts after the purchase subsidy was implemented. The results indicate that a Multi-stage DID method is suitable for the estimation [36].



Figure 1. Parallel trends of R&D efforts.

Table 4 presents the estimation results of Multi-stage DID. The coefficients of "du \times dt" are positive and significant at the 1% level in Model 1 and Model 2, which implies that purchase subsidy has stimulated the R&D efforts of NEV enterprises significantly. This result is consistent with existing literatures. For example, Horbach et al. [37] found that consumer subsidies can promote electrical vehicle enterprises' innovation in Germany, and Sun et al. [38] found that purchase subsidy has stimulated the technological breakthrough of electric vehicles in the USA. Purchase subsidy plays a key role in correcting innovation externalities, and may provide more opportunities for NEV enterprises to benefit from innovation [12]. In China, purchase subsidy granted for NEVs is matched with an improving technological requirement; purchase subsidy may stimulate enterprises' R&D efforts through creating more benefits for advanced technologies [39].

	Model 1	Model 2
Du × dt	0.007 ***	0.006 ***
	(3.18)	(2.82)
Sub		0.002 **
		(2.13)
Size		-0.010 **
		(-2.14)
Lev		0.031 **
		(2.36)
Age		-0.021
		(-1.62)
Profit		0.011
		(1.34)
Cons	0.057 ***	0.192 ***
	(7.06)	(2.68)
R ²	0.6287	0.6739
Ν	428	428

Table 4. Estimation results of DID.

Note: *t*-values are shown in parentheses. ***, ** represent significant levels at 1%, 5%, 10%, respectively.

The impact of the decrease of purchase subsidy rate is provided in Table 5. The coefficients of interaction terms (du × dt × Exit) in Model 3 and Model 4 are both positive and significant at the 5% level. This result indicates that, with the decrease of the purchase subsidy rate, purchase subsidy exerts a positive impact on the R&D efforts of NEV enterprises. Generous purchase subsidies may incentivize NEV enterprises to capture benefits from economies of scale. When the purchase subsidy rate is decreased, NEV enterprises had to increase R&D investment to obtain profits in the market. This is similar to the result of Ji et al. [40], who found that the decrease of the purchase subsidy rate promoted the development of NEVs.

Table 5. Impact of the decrease of the purchase subsidy rate.

	Model 3	Model 4
$Du \times dt \times Exit$	0.006 ***	0.005 **
	(2.87)	(2.52)
Sub		0.002 **
		(2.13)
Size		-0.010 **
		(-2.14)
Lev		0.032 **
		(2.40)
Age		-0.021
		(-1.62)
Profit		0.011
		(1.34)
Cons	0.057 ***	0.192 ***
	(7.04)	(2.68)
R ²	0.627	0.673
Ν	428	428

Note: t-values are shown in parentheses. ***, ** represent significant levels at 1%, 5%, 10%, respectively.

4.2. Impacts of Government Procurement and Exemption on Purchase Tax

The influences of government procurement and exemption on purchase tax are taken into consideration in Equation (3). Table 6 shows that the coefficients of "du \times dt" are positive and significant at the 5% level. This implies that the impact of purchase subsidy has not been influenced by government procurement and exemption on purchase tax.

	Model 5a	Model 6a	Model 7a	Model 5b	Model 6b	Model 7b
Du × dt	0.007 ***	0.006 ***	0.006 ***	0.006 ***	0.005 **	0.005 **
	(3.11)	(2.79)	(2.74)	(2.73)	(2.37)	(2.29)
Proc	0.002		0.001	0.004 *		0.004
	(0.54)		(0.47)	(1.69)		(1.63)
Exemp		0.006 ***	0.006 ***		0.006 ***	0.006 **
_		(2.70)	(2.66)		(2.59)	(2.56)
Sub				0.002 **	0.002 **	0.002 **
				(2.21)	(2.18)	(2.25)
Size				-0.010 **	-0.010 **	-0.010 **
				(-2.18)	(-2.15)	(-2.19)
Lev				0.031 **	0.030 **	0.029 **
				(2.34)	(2.30)	(2.28)
Age				-0.021	-0.021	-0.021
-				(-1.62)	(-1.63)	(-1.64)
Profit				0.012	0.011	0.012
				(1.41)	(1.33)	(1.40)
Cons	0.057 ***	0.056 ***	0.056 ***	0.193 ***	0.191***	0.192 ***
	(7.03)	(7.13)	(7.10)	(2.69)	(2.69)	(2.70)
\mathbb{R}^2	0.629	0.632	0.632	0.675	0.677	0.678
N	428	428	428	428	428	428

Table 6. Influences of government procurement and exemption on purchase tax for NEVs.

Note: *t*-values are shown in parentheses. ***, **, * represent significant levels at 1%, 5%, 10%, respectively.

The coefficients of "Proc" are insignificant at the 5% level across all models. This implies that government procurement has no significant impacts on R&D efforts of NEV enterprises, because the amounts of government procurement for NEVs are far below that of purchase subsidy, and government procurement is carried out with loose technological requirements. Furthermore, the fragmentation of government procurement may discourage enterprises' R&D efforts [13]. In sum, the government procurement can barely stimulate NEV enterprises' R&D efforts. This is consistent with existing literatures. For example, Finon and Menanteau [41] found that government procurement has no significant impact on technological innovation.

The coefficients of "Exemp" are positive and significant at the 5% level across all models. The results indicate that exemption on purchase tax has promoted the NEV enterprises' R&D efforts [42,43]. Similar to purchase subsidy, exemption on purchase tax was also conducted according to certain technological requirements. To obtain the qualification of exemption on purchase tax, NEV enterprises had to invest in R&D activities to meet the technological requirements.

5. Conclusions and Policy Implications

NEV enterprises may acquire technological competence through R&D efforts [11]. However, R&D activities in NEV enterprises may suffer from the 'double externality problems,' and result in underinvestment in enterprises' R&D activities [4]. Government subsidies are essential for compensating for the underinvestment. Purchase subsidies have been granted to accelerate the adoption of NEVs in China [18]. Whether these subsidies have stimulated the R&D efforts of NEV enterprises remains controversial. This study investigated the impact of purchase subsidy on the R&D efforts of NEV enterprises with a Multi-stage DID method. The results indicate that purchase subsidy has a positive

and significant impact on the R&D efforts of NEV enterprises, and the impact increases when the purchase subsidy rate decreases.

Purchase subsidy may create demands for new technologies of NEVs. However, a rapidly growing market may incentivize NEV enterprises to capture benefits from economies of scale through learning by doing, and depress the R&D investment in exploring new technologies [25]. What is worse, for the absence of effective supervision, some NEV enterprises may defraud purchase subsidies with inflated figures [44]. To stimulate the R&D efforts of NEV enterprises, the purchase subsidy rate should be reduced, and an effective supervision should be established [40].

The impact of government procurement is insignificant. This finding is inconsistent with previous studies [45,46], which suggest that government procurement has a positive impact on enterprises' R&D efforts. Due to the lack of advanced technological requirements, government procurement for NEVs is hard to stimulate R&D efforts of NEV enterprises [47,48]. However, with technological requirements, exemption on purchase tax has a positive impact on NEV enterprises' R&D efforts. To stimulate enterprises' R&D efforts, well-designed technological requirements should be set to couple with government procurement and exemption on purchase tax for NEVs.

The contributions of this study are as follows. First, since the amount of purchase subsidy granted to NEV enterprises cannot be separated from the gross subsidies, it is difficult to investigate the impact of purchase subsidy directly. To cope with this question, this study used a Multi-stage DID method to isolate the effect of purchase subsidy on NEV enterprises' R&D efforts. Second, the impact of decrease of the purchase subsidy rate is also estimated, which will contribute to address the effect of adjustment on purchase subsidy.

There are two limitations in our study. First, due to the limitation of sample size, the regulating effects of NEV enterprises' ownership and scale are not estimated in this study. Second, the dual-credit policy on NEV enterprises was implemented in 2018, and the panel data we used covered the period of 2008–2017, so the impact of dual-credit policy was not considered in this study.

Author Contributions: Conceptualization, C.J.; Data curation, Y.Z.; Formal analysis, Q.Z.; Writing—original draft, C.J.; Writing—review and editing, C.W. All authors have read and agreed to the published version of the manuscript.

Funding: Funding: This research was funded by Jiangsu Planning Office of Philosophy and Social Science grant number (16GLB002), Humanities and Social Science Foundation of the Ministry of Education of China (19YJA630029).

Conflicts of Interest: We declare that we have no conflict of interest.

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