Analysis of the impact of financial subsidies on R&D investment of new energy vehicle enterprises based on threshold regression

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Abstract. According to the news, a huge section of the current profit of NEV enterprises is attributed to state subsidies, while the state's financial subsidies for new energy vehicles have been decreasing year by year, showing a continuous downward trend. To remove the dependence of new energy companies on financial subsidies and make them more competitive in the future, their innovation and technological progress are particularly important. This paper investigates the impact of fiscal subsidies on NEV companies' R&D investment intensity of different scales through threshold regression and concludes that as the scale of enterprises expands, the motivating impact of fiscal subsidies on the R&D investment intensity of companies will achieve a qualitative leap at a certain point, and puts forward relevant suggestions for fiscal policy designation, refines the implementation methods and targets of fiscal subsidies, and offers some recommendations for the new energy vehicle industry's future sustainable growth. Additionally, it clarifies the objectives and implementation strategies for financial subsidies and offers some support for the future sustainable growth of the new energy vehicle sector.

Keywords: New energy vehicles; fiscal subsidies; threshold return; policy optimization.

1. Introduction

The development of technology of new energy vehicles has attracted a huge amount of attention recently because of the ongoing increase in global oil prices and the continuous improvement of environmental protection requirements [1].

The new energy industry in China has great prospects for development and has received great attention from the government. It is considered to be the future direction of automobile development because of its great environmental value and its curbing effect on energy use and is one of the seven strategic emerging industries that China is focusing on. However, China's NEV industry currently shows a great dependence on financial subsidies and a slowdown in technological progress due to the lack of investment in R&D. The future growth trend is not optimistic. Therefore, this paper explores the incentive effect of grant-in-aid on the R&D investment strength of the new energy vehicle industry through a literature review and empirical analysis, intending to provide more reasonable and detailed suggestions on the financial subsidies from multiple perspectives.

1.1 Background Research

1.1.1 The current state of the new energy vehicle industry

The overall outside situation is favorable. The global automotive industry is also at a crucial historical moment of transformation and upgrading and has entered the eve of comprehensive transformation and upgrading development of electricity, knowledge, and collaboration. The new round of technological revolution represented by new energy, new materials, and artificial intelligence is having a significant and far-reaching impact on global economic and social development. Electrification, which is a thorough upgrading of conventional vehicles, has emerged as a prominent trend in the growth of the global automobile industry as an efficient response to energy saving, environmental protection, and oil resource stress.

The growth of the new energy automotive sector is crucial for China's pursuit of high-quality automotive development and is crucial for the country's realization of a strong and sizeable automotive sector [2]. China developed new energy vehicles earlier [3]. The new energy vehicle sector in China has reached 1 million units in terms of production and sales after nearly 15 years of progress, ranking top around the world. The industry has gone through three stages of development since China formally announced the plan for electric cars: the first era is named the planning era, then followed by the introduction era, and finally the high-speed growth period.

As one of China's strategic emerging industries, the government has given the development of the new energy vehicle sector a high priority and has implemented a variety of incentive policies, which include budget subsidies for research and innovation, double points for manufacturing, financial subsidies and tax concessions for intake, infinite license plates and no acquisition limitations for use, and charging preferences for operation, nearly covering the entire life cycle.

China's new energy vehicles should focus more on high-quality research and development, speed up the advancement of new energy technology, increase the size of the new energy vehicle industry, and work to catch up with the growth of the global NEV industry as soon as possible. They should also take this opportunity to strengthen China's new energy technology's overall competitiveness [4].

1.1.2 The current state of financial subsidies

Since 2010, China has actively promoted the evolution of new energy vehicle promotion pilot projects and modified its automobile subsidy program in line with the situation [5]. Over 1,915,900 new energy vehicles have received more than 129.5 billion yuan in subsidies from China in the last 12 years. The total amount of subsidies for new energy vehicles in China will be 147.8 billion yuan if include the 18.3 billion yuan in pre-allocated funds for 2019–2020 that were announced by the Ministry of Finance. According to a more thorough analysis of the national ledger, each audited new energy vehicle could earn an average of 106,400 yuan in subsidies in 2015 and earlier, but in 2019 this amount has decreased to 57,000 yuan. From the viewpoint of automakers, the subsidy component is also decreasing as a share of income. Sales volume of new energy vehicles in China, meanwhile, rose year over year by more than 100% in 2009, 2014, and 2015, and increased more than 260 times in 12 years, from 5,209 units in 2009 to 1,367,000 units in 2020. Despite the outbreak, consumer interest is still high. China sold more than 2.5 million new energy vehicles in the first ten months of this year. According to the most recent data, the nation's fleet of new energy cars reached 6.78 million units as of September, making up 2.28% of all vehicles. 5.52 million of these are all-electric cars, making up 81.53% of the total number of new energy vehicles.

1.1.3 The current status and future trends of R&D investment of car companies

The new energy sector requires a lot of technology research and development because it relies heavily on technology as the engine of industrial growth. However, China has a challenge with the new energy sector's comparatively poor capacity for technological development. According to an analysis of the new energy industry's current state, China's new energy enterprises typically lack R&D personnel and resources, and while all types of R&D institutions have more adequate technical reserves, there is a gap between the research direction and the actual needs of the market phenomenon. The majority of companies in China's new energy sector currently focus primarily on processing and have high processing levels and large production capacities, but lack core technology mastery, resulting in lower added value to production and lower net profits that are confined to the factory of the technology owner. By actively promoting communication, exchange, and collaboration between businesses and R&D organizations in the new energy sector, highlighting the significance of market orientation in R&D work, and enhancing the industrialization capacity of technological innovation, thus can effectively raise the industry's overall technology level in China.

The worldwide new energy sector is currently expanding rapidly, and its newly installed capacity has surpassed that of conventional fossil fuels, signaling the "inflection point" of the alternation between old and new energy sources. According to an analysis of the state of the new energy sector at the moment, China's economic growth is in a crucial phase of curve-jumping, breaking through to

the new normal under the traditional energy overcapacity, renewable energy development bottlenecks, low overall operating efficiency of the energy system, and other unresolved issues. As a result, it's necessary to strongly support structural reform of the energy supply side while relying on the innovative development of new energy.

"The more we must strengthen autonomous innovation in the face of obstacles." According to Fu Yuwu, honorary director of the Chinese Society of Automotive Engineering, the innovation and transformation of the automotive industry is a long-term undertaking for businesses, and they must continue to explore and develop their core technologies despite the effects of the epidemic.

"Chinese automobile companies and international car companies are reaching unanimity in the investment in research and development." Industry experts predict that in the future, Chinese automakers' investments in R&D could surpass those of international automakers. Some of the newest auto manufacturing startups have already invested more in R&D than global corporations.

1.2 Research Significance

When the existing literature is summarized, it is clear that researchers have not come to a consensus regarding government subsidies' impact on business innovation. This effect is also influenced by various internal and external governance factors, and the existing conclusions are also based on different samples [6].

The targets of fiscal subsidies are scientifically classified in this paper so that a more detailed fiscal allocation policy can be provided. Additionally, the regression findings of this paper have implications for the implementation of fiscal subsidies, exposing the flaws of current fiscal subsidies and suggesting better improvement guidelines.

1.3 Research ideas and research methods

This study employs a threshold regression model type to examine the incentive of fiscal subsidies on R&D investment of listed new energy vehicle enterprises when the business scale is the threshold variable. It also employs a combination of literature surveys, empirical analyses, and other research methods to examine the impact of new energy vehicle subsidy policy on the sustainable development of new energy vehicle companies.

The paper first describes the applied data and data sources and calculation methods and conducts a descriptive analysis. Then a model is built using threshold regression, and according to the regression results, the conclusion that the incentive financial subsidies' impact on small- and medium-sized businesses' R&D investment is insignificant, and the effect on large enterprises is significant is obtained. Based on this conclusion, supplementary suggestions are made to the current financial subsidy policy, and finally, the arguments of this paper are summarized and reflected.

2. Data and Methodology

2.1 Data

Table 1. Variable Descriptions

Variable Type	Symbol	Meaning	Calculation	Source
Explanatory Variables	Rd	R&D investment intention	$\frac{R\&D\ investment}{Operating\ inome}$	CSMAR
Explained Variables	Scale	Enterprise size	$\ln Total\ assets$	Wind
Control Variables	Fs	Financial Subsidies	$Financial\ statement\ data$	Wind
	Npi	Net profits Index	$\frac{Net\ profit}{Marketing\ revenue} * 100\%$	Wind
	At	Asset Turnover	$Sales\ revenue/((Total\ assets_{beginniing} + Total\ assets_{end})/2)$	Wind
	Alr	Asset-Liability Ratio	$\frac{Total\ liabilities}{Total\ assets}$	Wind
	Cr	Current Ratio	$\frac{Current\ assets}{Current\ liabilities}$	Wind

Table 1 above shows variables that are included in the model setting and demonstrate the calculation and sources of variables.

2.1.1 Dependent variables and sample

The independent variable is the R&D investment ratio of new energy vehicle enterprises (Rd) defined as the ratio of the amount of corporate investment in R&D to the operating revenue of the enterprise in the current year (Data Source: CSMAR). The definition of the dependent variable avoids the discrepancy in the amount of R&D investment due to the scale of the enterprise.

This paper selects the data of listed companies in Shenzhen and Shanghai A-shares in China during the ten years from 2010 to 2020, because the new energy industry is more volatile in 2021 due to the impact of the epidemic, and the impact on small and medium-sized car companies is more obvious, this paper excludes data for 2021. As of December 31, 2020, there are 416 listed vehicle companies in the new energy sector, excluding ST and *ST companies and missing companies, the remaining 310 vehicle companies panel data, a total of 1860 sample data.

2.1.2 Independent Variables

The independent variables of this model are financial subsidies, and the data source is the non-operating income section of the annual reports of listed companies in the Wind database.

2.1.3 Control Variables

This paper evaluates the operating conditions of new energy vehicle companies through five aspects, including liquidity, asset management ratio, debt ratio, and profitability ratio. For each aspect, a common and authoritative indicator in the field of economics is selected for evaluation, and these indicators can be calculated according to the annual reports of vehicle businesses (source: Wind). As a common indicator, the current ratio reflects the liquidity of an enterprise, and the smaller the current ratio, the smaller the short-term debt-servicing ability of an enterprise; the asset turnover ratio reflects the asset management ability of an enterprise, and the higher the asset turnover ratio means the faster the turnover speed, which can be used in combination with the profitability indicator (net sales margin) to evaluate the profitability of an enterprise more comprehensively; in addition, this model, In addition, this model selects the control variable of asset-liability ratio to assess the financial risk faced by the enterprise.

2.2 Methodology

Through the analysis of the enterprise panel data, this paper finds that the Scale difference of new energy vehicle enterprises is too large to draw accurate conclusions by simple linear regression. Therefore, a threshold regression model is used to process the data. The basic idea is as follows: a particular variable is chosen as the threshold variable, the regression model is divided into several intervals based on the threshold value sought, the expression of the regression equation is different for each interval, and the other sample values are categorized based on the interval divided by the threshold. Finally, after regression, the changes in the coefficients of various intervals are compared.

In Equation (1), fiscal subsidies (Fs) are used as the core explanatory variables, and βX is a set of control variables that affect the operating conditions of enterprises, including Net Profit Index (Npi), Asset Turnover (At), Asset- Liability Ratio (Alr), and

Current Ratio (Cr). Considering that the effect of fiscal policy will be different under different enterprise sizes, the enterprise size (Scale) is used as a threshold variable to examine the effect of fiscal tools on R&D investment of new energy vehicle enterprises when the companies size is the threshold, and the model equation is as follows.

$$Rd = \beta_0 + \beta_1 sub_{it} I(scale_{it} \le \gamma_1) + \beta_2 sub_{it} I(\gamma_1 < scale_{it} \le \gamma_2) + \cdots + \beta_n sub_{it} I(scale_{it} > \gamma_n) + \beta X_{it} + \varepsilon_{it} \quad (1)$$

3. Result

3.1 Data Analysis

Table 2. Descriptive Statistics

	N	Min	Max	Mean	Std. Deviation
Rd	1860	0	0.4232	0.0501	0.0370
Fs	1860	1980	6380	4026	1337.843602
Scale	1860	19.7053	27.5473	22.2652	1.2820
Npi	1860	0.0039	0.8319	0.2131	0.1123
Alr	1860	0.0322	1.6499	0.4258	0.1846
Cr	1860	0.1065	24.2261	2.2501	2.0249
At	1860	-1.6463	29.5414	0.3103	1.1076

Based on table 2 above, can be summarized as：

The intensity of R&D investment varies greatly among different new energy vehicle enterprises. The smallest investment intensity in the sample is 0, and the maximum value is 42.32%.

The difference in the amounts of financial subsidies is obvious, with the highest value reaching RMB 638 million/year and the lowest value at RMB 198 million/year, which shows that the government supports the new energy industry strongly, but the support for enterprises of different scales is not quite the same.

Comprehensive analysis of the Net Profit Index, Asset-Liability Ratio, Current Ratio, and Asset turnover data shows that the operating conditions of car companies differ greatly, among which Asset-Liability Ratio, Current Ratio and Asset turnover data show that the operating conditions of car companies differ greatly.

The range of the Liability Ratio reaches a staggering 152%, and the extreme differences between the remaining three indices are also very large. The business status and firm size are closely related, so the need to use firm size as a threshold variable arises so that the association between financial subsidies and R&D investment can be studied more effectively.

3.2 Regression Analysis

Table 3. Threshold estimation results

Threshold variable	Explanatory variable	Model	Threshold estimates	95% confidence interval	
	tax	Single Threshold	21.272	21.228	21.293
	Fs	Single Threshold	21.272	21.228	21.293

As table 3 illustrated:

First, the regression helps to test whether the relationship between policy instruments and the R&D investment intensity of firms undergoes non-linear abrupt changes when firm size is the threshold variable. In order to obtain t h e corresponding F-values and P-values, model (1) is "auto sampled" 100 times. The results show that the model has a threshold effect, i.e., when the firm size (Scale) is the threshold variable and a single threshold effect with financial subsidies (Fs) as the core explanatory variable, with a threshold value of 21.272. The model is therefore adjusted as follows.

$$Rd = \beta_0 + \beta_1 Fs_{it} I(size_{it} \leq 21.272) + \beta_2 Fs_{it} I(size_{it} > 21.272) + \beta X_{it} + \varepsilon_{it} \quad (2)$$

3.3 Regression Results

Table 4. Regression results

$Variables$	Fs
$Fs(Scale \leq 21.272)$	0.110**
	(2.046)
$Fs(Scale > 21.272)$	0.126**
	(2.373)
$Constants$	-5.341
	(-1.590)
R^2	0.264

According to the threshold value shown in table 4, it can classify the enterprises whose size is smaller than 21.272 (threshold value) as small and medium-sized enterprises, and those larger than 21.272 as large enterprises. According to the regression results, it can be concluded that firstly, financial subsidies have a positive incentive on the R&D intensity of new energy vehicle enterprises; secondly, the incentive effect on large vehicle enterprises is greater than that on small and medium-sized vehicle enterprises, which means that the sensitivity of their R&D investment to financial subsidies increases significantly when a threshold is crossed as the scale of vehicle enterprises increases.

4. Suggestions

4.1 Policy Implementation

4.1.1 Regulatory Policy

The government must monitor and provide feedback on the subsequent use of funds if financial subsidies and tax incentives are to effectively play their part in China's new energy vehicle industry's promotion. The majority of new energy vehicle companies behave "fraudulently" as a result of the Chinese government's inadequate efforts in this area, which not only wastes national financial resources but also deters those who adhere to the rules and work to develop new energy vehicle manufacturers [7].

The implementation of policy in accordance with the actual problem of continuous improvement and adjustment, to achieve a dynamic balance, is the sustainable development of practice. The relevant departments continue to introduce measures to strengthen regulation, with the gradual tightening of regulation, but also randomly generated a new energy vehicle enterprises capital chain tension [8]. The government should introduce policies that are friendly to new energy vehicles, appropriately provide financial subsidies for technological innovation, and continue to implement positive guidance policies. Additionally, the government should have a thorough understanding of the new energy vehicle industry environment.

However, the "subsidy" policy offers very few incentives for R&D spending in new energy vehicle enterprises, and Chinese new energy vehicle firms have yet to make significant strides in essential technologies [9]. It is vital to reduce the use of "subsidy" policies as well as other state resource allocation mechanisms and use "non-subsidy" policies to play a pivotal role in market available resource allocation in order to limit the excessive dependence on new energy vehicle enterprises the establishment of the driving force for technical innovation of new energy vehicle firms on government fiscal and tax assistance.

4.1.2 Subsidy Policy

It is not difficult to discover that China still needs to make additional advances in core technology, innovate on its own, and master the technology of core components in its own hands in order to adapt to the rapid development of the new energy industry through the study of Panasonic and Tesla and other models with strong inter-pressure competitiveness [10]. Enterprises must be certain of the new energy vehicle technology's development direction because they cannot always cling to their

advantageous technologies. After all, as technology advances to a more advanced stage, the corresponding technical advantages may become technical disadvantages. As a result, enterprises must actively pursue emerging technologies in order to provide the impetus for sustainable development [11]. Enterprises should always maintain the idea of management innovation, have their own management innovation ideas, not follow the trends, pay attention to the development of innovation culture, and continuously improve the capacity of enterprise management innovation in the context of environmental changes. Enterprise management innovation is the central driver of enterprise productivity, and a company that wants to grow should focus on its capacity for innovation. In the modern business environment, management innovation is crucial for company growth. To foster stable and quick company growth, companies must first have a stable management approach to lay the groundwork for innovation.

Apart from that, according to the regression results, the paper can get that the process of quantitative change will lead to qualitative change as the companies grow into large car companies. In the early stage of financial subsidies, the paper may not see the technological progress and leap of the enterprises, but with continuous subsidies, the enterprises will grow gradually and at some point will create a technological barrier to achieving technological innovation. Therefore, as a policymaker, you should not be too hasty but should look at the long term. The long-term benefits of financial subsidies for technology incentives in 10 or 15 years are considerable.

4.2 Implement Object

Large automakers are those that receive the most subsidies, with BYD receiving the most in this instance with 155,000 vehicles approved and 3.98 billion yuan in subsidies, or more than 12% of the total amount of subsidies [12]. With an average annual profit of about 3.5 billion yuan and a total net profit between 2016 and 2020 of 17.746 billion yuan, BYD benefited from an additional year of "year-end bonus" as a result of receiving this subsidy. The second-ranked BAIC received 3.51 billion yuan in subsidies, but BAIC New Energy received 1.8 billion yuan in subsidies, while BAIC New Energy's total net profit from 2016 to 2020 was -6.291 billion yuan or roughly one-third of the loss recovered by BAIC New Energy with subsidies. Third-placed Dongfeng Motor received 2.34 billion yuan in subsidies. Furthermore, Tesla had 101,000 vehicles approved with subsidies totaling 2.12 billion yuan, of which Tesla will sell 148,000 vehicles in the Chinese market in 2020, and the vehicles approved for liquidation accounted for 68% of Tesla's sales in that year. Additionally, some major automakers received very little subsidy because they did not fulfill the requirements for receiving it.

China's new energy vehicle subsidies are currently cleared primarily based on whether the new energy model range complies with standards; however, the introduction of enterprise size classification in the future may increase the likelihood that subsidies will be implemented for R&D investment. In the meantime, support for small and medium-sized businesses should be maintained and gradually increased so that, when they expand into major businesses, they can take a step forward in R&D.

4.3 Research gaps and outlook

The sample size is too small and this paper's sample size can be enhanced. However, many small businesses are not included in the present new energy vehicle boom and are not included in this work because of their inadequate data sharing, etc. The current sample consists of the new energy vehicle enterprises listed in the Wind database. The regression results of this paper will be more precise if there is a more complete database to cover these tiny businesses.

The policy interpretation is cursory, and the depth of thought put into it is insufficient. The recommendations for the program are overly idealistic and fail to account for the opposition and national budgetary pressures that will arise when the policy is actually put into practice.

5. Conclusion

This study uses threshold regression to examine the impact of financial subsidies on the R&D investment intensity of new energy vehicle firms of various sizes. According to the descriptive analysis of the data, it can be found that the R&D investment intensity of car companies and the variance of the size of car companies with range is large, and if the regression analysis is carried out directly without classifying the size of the companies, the fitting effect will not be very good and the conclusions obtained will not be very constructive. Therefore, I use the threshold regression to regress the enterprise size as the threshold variable and obtain that the enterprise R&D investment intensity of small and medium-sized enterprises is less sensitive to financial subsidies, and large enterprises are more willing to apply financial subsidies to R&D investment This conclusion. Based on this conclusion, it can refine the policy implementation and the target of financial subsidies for more in-depth elaboration, and reflect on the shortcomings of the existing monetary and the ways to improve it. The former can be improved by supplementing a more comprehensive database, and the latter can be improved by more in-depth study and research.

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