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Sustainability of the New Energy Automobile Industry: Examining the Relationship among Government Subsidies, R&D Intensity, and Innovation Performance

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Abstract: One of the most important factors in fostering the sustainable growth of the world economy is the global green low-carbon transition. With its effective use of resources, its high technological requirements, and its high added value, the new energy vehicle industry exemplifies the potential for sustainability. Its growth satisfies the requirements of China's transition to an economic growth mode. This study performs an empirical analysis, using panel data from 154 new energy vehicle companies for the years 2015 to 2020. It examines the role of research and development (R&D) intensity in the impact relationship between government subsidies, R&D intensity, and innovation performance. The study's results reveal that government subsidies have a significant positive influence on the innovation performance of enterprises, with this effect being more pronounced in non-state-owned and large-scale enterprises. Moreover, the mechanism analysis indicates that R&D intensity serves as a mediator between government subsidies and innovation performance. Based on this, this paper proposes that the government should refine the subsidy policy and should scientifically classify the enterprise standards and that enterprises should enhance their R&D capability and should develop innovation mechanisms.

Keywords: government subsidies; R&D intensity; innovation performance; new energy automobile industry

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1. Introduction

The contemporary global landscape is confronted with the profound challenge of climate change, which has far-reaching and detrimental consequences. In light of this, all countries must update their low-carbon emission strategies, taking into account their respective renewable energy resources and identifying the most promising avenues for enhancing energy efficiency [1]. "Carbon neutrality" has become a growing trend [2]. The ecological economic theory of American scholar Lester Brown notes that the first step towards achieving sustainable economic development is to actively promote energy change. He suggests that, given the grave threat posed by "global warming," it should be "transformed as soon as possible from a fossil fuel (oil, coal)-centered economy to a solar, hydrogen energy-based economy" [3]. The process of decarbonizing the vehicle sector plays a significant role in achieving the carbon reduction objectives. The automotive industry exhibits several key characteristics, including a lengthy industrial chain, extensive radiation, rapid increase in overall carbon emissions, and high carbon intensity of a single vehicle. These factors make it a crucial sector for achieving carbon neutrality and advancing the national energy transition [4]. New energy vehicles have the potential to achieve coordinated development with renewable energy by utilizing energy storage, peak shifting, and energy consumption [5]. The vigorous development of the new energy vehicle industry serves as a significant approach to facilitate the establishment of a novel power system and expedite the resolution of energy and environmental limitations. Additionally, it is a crucial means of achieving peak carbon neutrality [6]. The automotive new energy sector offers significant positive externalities [7]. The new energy automotive industry, one of the high-tech sectors, has a greater need for the amount of capital and for its steady supply, while also needing to sustain the continuity of innovation in science, technology, and other areas [8]. The Chinese government has implemented a variety of regulations to assist the growth of the new energy automotive industry to ensure the long-term development of the sector [9]. In the report "New Energy Vehicle Industry Development Plan (2021–2035)" released by China in 2020, it is proposed to enhance the core technology innovation, strengthen the infrastructure construction, and improve the industrial layout, so that the new energy automobile industry can meet the new standards and requirements and the product quality level can be improved comprehensively [10]. In the development process of the new energy automobile industry, the production side needs a lot of R&D and infrastructure investment, while the consumer side needs incentives to guide consumers to change their concept of consumption because of the need to replace the traditional automobile products. Both sides have a greater demand for "mobility" [11,12]. The government uses subsidies to inject external funds into the new energy vehicle industry chain to realize the sustainable development of new energy vehicles [13]. The development of the new energy vehicle industry cannot be separated from the support of government subsidies and the improvement in its R&D capability. However, what is the mechanism between government subsidies, R&D intensity, and innovation performance? Can government subsidies improve the innovation performance of enterprises by promoting R&D intensity?

The objective of this study is to incorporate government subsidies and company innovation performance under a unified research framework. It seeks to investigate the influence of government subsidies on innovation performance while considering R&D intensity as a mediating variable. For new energy automobile enterprises, the government invests a lot of money every year to help their development, but whether the invested money promotes the improvement in enterprise innovation performance fundamentally is a key practical issue. Simultaneously, the current body of literature about the examination of the influence of government subsidies on the innovation performance of enterprises exhibits incongruous findings, mostly because of variations among industries. Moreover, there is a dearth of research specifically investigating the new energy automotive sector in this context. Therefore, the research contribution of this paper is mainly reflected in three aspects. Firstly, it enriches the theory of technological innovation. Implementing a government subsidy policy that is directed toward new energy vehicle enterprises, with directed universality, stability, and transparency, may effectively encourage these enterprises to enhance their research and development (R&D) investments in important core technology domains. Additionally, such a policy can provide support for common technological research and development, hence facilitating the release of innovation potential inside these enterprises. Secondly, it enriches the theory of ecological economy. The new energy automobile industry plays a significant role in expediting the energy science and technology revolution. It not only supports and guides the high-quality development of energy but also fosters the growth of energy technology and its associated industries as a new catalyst for enhancing the optimization and advancement of related industrial chains. Simultaneously, the research in this paper has certain practical significance. Thirdly, for enterprises, the research results of government subsidies on innovation performance can help enterprises focus on R&D intensity, improve the level of innovation, and are of great significance to the construction of intelligent and modernized industrial chains. For the government, the research results provide support for the government to optimize its support policies. The government should adapt to the development law of the market, dynamically adjust the amount and intensity of subsidies, and promote the rational allocation of resources. To address these issues, Section 2 of this study formulates the research hypotheses through a theoretical analysis. In Section 3, a sample of 154 new energy automobile enterprises from 2015 to 2020 is utilized, and the selection of variables is determined. In Section 4, an empirical analysis is conducted to systematically assess the impact of government subsidies on R&D intensity and innovation performance, while it also examines the mediating role of R&D intensity between government subsidies and innovation performance. Section 6 of this essay is the conclusion.

2. Theoretical Analysis and Research Hypothesis

2.1. Government Subsidies and Innovation Performance

By investing in R&D, businesses foster production and innovation, boosting economic growth and competitiveness [14]. However, as the innovation process has the attribute of public goods, it is difficult for enterprises to fully capture the private benefits. This can result in the return on innovation inputs being less than the social return; in the phenomenon of market failure, it is necessary for the government to appropriately incentivize and intervene in the innovation activities of enterprises, and the theoretical basis for supporting the government subsidy must also be confirmed [15]. Government subsidies are an important launching pad for the formation of the national innovation system, aiming to enhance the innovation capacity of enterprises so as to further enhance the comprehensive strength of industrial development [16]. With the continuous development of and improvement in the theory, the research on government subsidies has also shown a more in-depth trend. Scholars no longer focus only on the role of the overall subsidy; they are more focused on the subsidy effect on innovation performance [17].

From the perspective of direct financial impact, government subsidies for innovation constitute a significant external funding source for firms engaged in innovative activities [18]. Government subsidies significantly lessen the financial strain on businesses during the early stages of innovation and assure that it will continue [19]. Government subsidies for innovation lower R&D costs, lessen market failure losses, make technological innovations with low expected returns profitable, and improve company innovation performance [20]. When businesses engage in research and development (R&D), information asymmetry is unavoidable; therefore, information exchange is essential in maximizing business innovation output [21]. The degree of mutual trust between businesses and the manner in which information is shared can provide quicker and more accurate information access between businesses and can ensure that businesses receive the information required for innovation output. Government subsidies are an effective way of endorsement; they can effectively alleviate the problem of asymmetry in the communication and transfer of information between local policy makers and enterprises, and they can improve the local market environment [22].

The internal decision-making motives of firms of different ownership types are subject to institutional constraints; this can lead to differential incentive effects of government subsidies on innovation inputs among firms of different ownership types [23]. State-owned enterprises have problems in operational efficiency, internal systems, and management relative to non-state-owned enterprises; this has been confirmed in studies on ownership structure and enterprise performance [24]. Enterprise internal processes, including operational effectiveness, systems, and management, have an impact on R&D operations. When the government finances an organization's R&D and innovation efforts, their effects must be seen internally. Additionally, as an organization's share of the state-owned economy increases, the government's influence over innovation performance decreases [25]. Simultaneously, considering variations in firms' experience, enterprises with extensive experience are those that have a prolonged history, substantial scale, and endowed resources. In such enterprises, government subsidies are more likely to bolster innovation performance when integrated as part of R&D investment for innovation activities [26]. As a result, the following hypothesis is put forth:

H1. *Government subsidies improve firms' innovation performance.*

2.2. Government Subsidies and R&D Intensity

Both viewpoints of the company's size and market structure are primarily used in Schumpeter's theory of technical innovation to demonstrate the key variables influencing the company's innovation and development [27]. As the main body of new energy technology innovation and R&D investment, new energy automobile enterprises rely on government support to increase the intensity of R&D, to master the core technology, and to form core competitiveness [28]. Based on the existing literature, according to the enterprise size, enterprise nature, and the difference between the government subsidy rate, scholars have found that in the government subsidy on enterprise R&D investment, there are different effects, but most think that there is a promotional effect on enterprise R&D investment [29,30]. Nonetheless, government subsidies will decrease the enterprise's spontaneous R&D expenditure since they have a crowding-out effect on business R&D spending. Due in part to the fact that new energy automotive firms lack the requisite risk awareness in the administration and use of government subsidies, the majority of the outcomes of this type of study are focused on the late 20th and early 21st centuries and are occurring in a unique historical period [31]. Every stage of R&D activities necessitates people and equipment changes in accordance with the progress of R&D; however, the majority of new energy firms exhaust their subsidy money at the early stage of R&D, leading to the weak intensity of subsequent R&D investment [32].

With the evolution of policies, enterprises have shifted their focus toward the strategic management of long-term research and development (R&D) investments. Meanwhile, the government has gradually refined the supervisory framework to ensure the effective allocation of subsidies, thereby transitioning the impact of government subsidies on enterprise R&D investment from a crowding-out to a crowding-in effect [33]. Government oversight, direction, and assistance are essential for businesses to conduct technical research and development while maximizing the protection of their inventive achievements [34]. Government subsidies can significantly lessen the financial pressure and the restrictions that new energy businesses face from outside sources by giving them financial support and by encouraging R&D spending [35]. On one hand, government support policies for new energy enterprises can reduce R&D costs, thereby narrowing the gap between the return on R&D activities and the optimal return to society, improving the return on R&D activities, and thus promoting R&D investment [36]. Government support policies for new energy enterprises can reduce R&D costs, thereby narrowing the gap between the return on R&D activities and the socially optimal return, increasing the return on R&D activities, and thus promoting R&D investment [37]. On the other hand, government subsidies can enhance the R&D innovation ability of new energy enterprises. This is so that new energy businesses can acquire cutting-edge engineering and scientific knowledge, which will improve their technological prowess and, in turn, their capacity for creativity [38]. In addition, subsidies can also expand the high-tech talent pool of new energy enterprises. Reduced demand for R&D allows new energy companies to hire more highly qualified researchers, which strengthens support for R&D activities. Based on this, the following hypothesis is formulated:

H2. *Government subsidies can increase firms' R&D intensity.*

2.3. R&D Intensity Mediates between Government Subsidies and Innovation Performance

R&D capability limits the innovation and development capability and the core competitiveness of firms, which is a key factor in assessing the innovation performance of new energy automobile enterprises and their sustainable development [39]. When engaging in R&D innovation, businesses must take into account their strengths and use the level of R&D expenditure as a basis for reflection on whether they have the foundation for doing so [40]. R&D investment is conducive to prompting enterprises to invent new products and to create new processes; this enhances the added value of products and promotes the improvement in innovation performance represented by patents, new products, and other innovative outputs to ensure the sustainable development of enterprises [41]. When undertaking R&D investments, new energy automotive companies deal with the traits of high risk, large investment, and a lengthy recovery cycle. If the R&D investment is effective, it is anticipated that using new technology will lower the cost of the product, increasing the product's competitiveness and market share, and enhancing the enterprise's performance in terms of innovation [42].

Government subsidies increase R&D capital for enterprises while also reinforcing a solid foundation for innovation that promotes the innovation performance of enterprises [17,35]. Therefore, there must be some kind of linkage between government subsidies and innovation performance. After the government subsidies enter the enterprise, it affects the R&D intensity of the enterprise, which motivates the enterprise to carry out innovative activities and enhances the innovation performance of the enterprise [43]. Government subsidy programs act as guidelines for businesses, directing them to increase R&D spending, to increase R&D intensity, and to fortify various aspects of business performance [44]. R&D investment has a positive impact on firms' innovation performance and also generates positive spillover effects at the national level [37]. Accordingly, governments actively encourage businesses to increase their R&D spending to reduce the inherent R&D risks and offer financial incentives to do so [45]. These government subsidies are distributed based on the size of the company's R&D investment and on the resulting impact that it produces. By increasing their R&D spending, businesses are given more freedom to innovate; these policies also make it easier for businesses to secure government funding [46]. Therefore, the following hypothesis is proposed:

H3. *Government subsidies improve firms' innovation performance by increasing R&D intensity.*

3. Research Design

3.1. Sample Selection and Data Sources

This study selected 154 new energy automobile enterprises from the years 2015 to 2020 as the research subjects. The China WIND database, the CSMAR database, and the publicly available annual reports were applied to gather information on variables like the number of patent applications, the total amount of government subsidies, and the intensity of R&D spending. The following criteria were used to determine which samples should not have been included in the analysis: (1) companies that were not listed during the sample period; (2) companies that had serious financial problems; (3) companies that had financial data that were incomplete or that had missing values; and (4) companies that lacked core data during the sample period. After the screening, 154 new energy automotive firms provided a total of 924 sample observations for the period from 2015 to 2020. To arrive at empirical study conclusions, a regression analysis was applied to the sample data that had been gathered.

3.2. Definition of Variables

3.2.1. Explained Variables

Existing studies often divide methods of gauging companies' innovation performance into two categories; one uses either the number of patent applications [47–49] or the number of patent citations [50] as a measurement indicator. The other is to gauge innovation performance by analyzing new product sales [51]. However, regulations do not require firms to disclose new product sales revenue data in their annual reports. Therefore, based on the availability of data, this paper takes the number of patent applications as a measure of the innovation performance of new energy automobile enterprises and then takes the natural logarithm of the original data plus one.

3.2.2. Explanatory Variables

Government subsidies are either direct or indirect financial aids provided by the government to certain enterprises with established regulations, aiming to facilitate the fulfillment of specific business objectives [52]. In this study, government subsidies serve as an explanatory variable; the data mainly comes from the manual query to collect the number of government subsidies in the annual report information of the sample enterprises. Take the natural logarithm of the data to improve stability.

3.2.3. Intermediary Variables

R&D intensity is one of the most crucial measures of an organization's capacity for autonomous R&D, which has an enormous effect on the innovation output of the company. Building upon prior research, this study employs R&D investment intensity as an explanatory variable, quantifying R&D intensity using the ratio of enterprise R&D investment to operational income [53].

3.2.4. Control Variables

In addition to the two variables of government subsidies and the R&D intensity, other factors, such as the nature of the enterprise and the business income of the enterprise, also affect the innovation performance of new energy automobile enterprises to different degrees. This may cause the empirical results to deviate from expectations [23,24]. To effectively avoid such a situation, this study takes the following six indicators as control variables:

(1) Growth rate of operating income (OIG). To a certain extent, it reflects the business ability of enterprises, and good business ability can promote the improvement in enterprise innovation performance.
(2) Gearing ratio (GR). In instances when the gearing ratio is too elevated, corporations tend to curtail their capital allocation towards research and development (R&D) and innovation endeavors.
(3) Return on assets (ROA). A high return on assets indicates that the firm can have sufficient funds available to carry out innovative activities.
(4) Enterprise size (SIZE). Large-scale enterprises generally have a stable financial chain, a large percentage of highly qualified employees, and a high tolerance for risk, all of which might encourage enterprises to engage in creative activity.
(5) Equity concentration (TOP1). Enterprises with high equity concentration are not conducive to innovative R&D activities.
(6) Enterprise nature (NAT). The companies are placed into two categories: state-owned and non-state-owned, with a value of 1 and 0, respectively, based on factors such as the real controlling owner. The specific variables are defined in Table 1.

Table 1. Variable definition table.

Variable Type	Variable Name	Variable Symbol	Variable Description
Explained Variables	Innovation Performance	PAT	The logarithm of the number of patent applications plus one
Explanatory Variables	Government Subsidies	SUB	The logarithm of the number of government grants
Intermediary Variables	R&D Intensity	R&D	R&D Investment/Revenue
Control Variables	The growth rate of operating income	OIG	Growth in operating income/Total operating income of the previous year
	Gearing Ratio	GR	Total liabilities at the end of the period/Total assets at the end of the period
	Return on Total Assets	ROA	Net profit/Average total assets

Table 1. *Cont.*

Variable Type	Variable Name	Variable Symbol	Variable Description
Control Variables	Enterprise Size	SIZE	The logarithm of total assets
	Top1	Top1	The shareholding ratio of the largest shareholder
	Enterprise Nature	NAT	1 for state-owned, 0 for non-state-owned

3.3. Model Setting

This study focuses on the impact of government subsidies on enterprise innovation performance. To test Hypothesis 1, government subsidies are put into the regression model as explanatory variables and enterprise innovation performance as explained variables. Meanwhile, the research sample enterprises are further analyzed for heterogeneity, according to the nature and size of the enterprises, to determine whether government subsidies can improve the innovation efficiency of enterprises. Consequently, Model (1) is created as follows:

$$PAT = \alpha_0 + \alpha_1 SUB + \alpha_2 OIG + \alpha_3 GR + \alpha_4 ROA + \alpha_5 SIZE + \alpha_6 TOP1 + \alpha_7 NAT + \varepsilon \quad (1)$$

In order to test Hypothesis 2, the effect of government subsidies on the R&D intensity of new energy automobile enterprises, Model (2) is established as follows:

$$R\&D = \alpha_0 + \alpha_1 SUB + \alpha_2 OIG + \alpha_3 GR + \alpha_4 ROA + \alpha_5 SIZE + \alpha_6 TOP1 + \alpha_7 NAT + \varepsilon \quad (2)$$

Model (3) is developed to test Hypothesis 3, which states that the relationship between government subsidies and innovation performance is driven by the intrinsic mechanism of R&D intensity:

$$PAT = \alpha_0 + \alpha_1 SUB + \alpha_2 R\&D + \alpha_3 OIG + \alpha_4 GR + \alpha_5 ROA + \alpha_6 SIZE + \alpha_7 TOP1 + \alpha_8 NAT + \varepsilon \quad (3)$$

In the above model, PAT stands for firms' innovation performance. R&D stands for firms' R&D intensity, and SUB stands for government subsidies. OIG, GR, ROA, SIZE, TOP1, and NAT are some control variables. ε is the random error term.

4. Empirical Results and Analysis

4.1. Descriptive Statistics

As can be seen from Table 2, the mean value of innovation performance (PAT) is 5.303, and the standard deviation is 1.517, which shows that new energy automobile enterprises of different size types have large differences in innovation capability. The gap between the maximum value and the minimum value of innovation performance (PAT) is 8.027, which also illustrates the point. The difference between the maximum value and the minimum value of government subsidies (SUB) is 7.06, and the difference between the mean value and the standard deviation is 15.832, reflecting that the amount of government subsidies allocated to different enterprises in the new energy automobile industry varies greatly. In addition, the same situation exists for R&D intensity. The mean value of R&D intensity is 0.0493, and the maximum value is 0.475. The maximum value is nearly ten times the mean value, reflecting a large gap in R&D intensity between different enterprises. This is due to the variability of enterprise size; small-scale enterprises often have the problem of insufficient funds and capabilities required for technological research and development, reflecting, from the side, that government subsidies have an important role in supporting the R&D behavior of enterprises with insufficient funds.

Table 2. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
PAT	924	5.303	1.517	1.386	9.413
SUB	924	17.22	1.388	14.14	21.20
R&D	924	0.0493	0.0354	0.000533	0.475
OIG	924	0.158	0.278	−0.332	1.391
GR	924	0.441	0.164	0.100	0.794
ROA	924	0.0325	0.0540	−0.224	0.153
SIZE	924	22.62	1.119	20.54	26.19
TOP1	924	0.307	0.139	0.0438	0.650
NAT	924	0.258	0.438	0	1

By observing that the average value of the operating income growth rate (OIG) is 15.8% and that the maximum value reaches 139.1%, we see that new energy automobile enterprises are currently in the growth period and have a good momentum of development. The difference between the maximum and minimum values of the gearing ratio (GR) is obvious, which indicates that some enterprises have a poor ability to utilize external assets or higher risk. The maximum value of return on assets (ROA) is 15.3%, and the average value is 3.25%, which indicates that new energy automobile enterprises are not very profitable and are easily affected by the macro environment of the market, with low-risk resistance. The maximum value of equity concentration (TOP1) is 65% and the minimum value is 4.38%, indicating that there is a big difference in the power of shareholders in the new energy automobile industry, and some shareholders have a poorer ability to control the enterprise.

4.2. Correlation Analysis

As shown in Table 3, the correlation coefficient between government subsidies (SUB) and innovation performance (PAT) is 0.537. There is a strong positive correlation at the 1% level. This means that the more government subsidies an enterprise receives, the more its innovation performance will advance. The correlation coefficient between R&D intensity (R&D) and innovation performance (PAT) is 0.230, which indicates that the higher the R&D intensity, the better the corresponding innovation performance will be. The government subsidies have a favorable impact on firm R&D intensity, as shown with the correlation coefficient between government subsidies and innovation performance, which is 0.076 and is significant at the 5% level. The correlations between the variables are all in line with the previous hypothesis. Additionally, none of the correlation coefficients in the table are greater than 0.6, indicating that there is no multicollinearity because the link between the variables is regarded to be weak.

Table 3. Variable Pearson correlation coefficient matrix.

	PAT	SUB	R&D	OIG	GR	ROA	SIZE	TOP1	NAT
PAT	1								
SUB	0.537 ***	1							
R&D	0.230 ***	0.076 **	1						
OIG	−0.039	−0.03	−0.105 ***	1					
GR	0.318 ***	0.385 ***	−0.082 **	−0.022	1				
ROA	0.045	0.052	−0.137 ***	0.286 ***	−0.278 ***	1			
SIZE	0.506 ***	0.818 ***	−0.135 ***	0.003	0.494 ***	0.059 *	1		
TOP1	0.143 ***	0.081 **	−0.215 ***	−0.003	0.035	0.201 ***	0.116 ***	1	
NAT	0.162 ***	0.272 ***	−0.030	−0.068	0.263 ***	−0.033	0.324 ***	0.144 ***	1

The ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively, with standard errors in parentheses.

4.3. Regression Analysis

4.3.1. Testing the Relationship between Government Subsidies and Innovation Performance

The regression coefficient of government subsidies (SUB) on the performance of innovation (PAT) in the new energy automotive industry is 0.112, as shown in Table 4, and it is significant at the 5% level. This demonstrates that government subsidies have certain promotion-like effects on the performance of business innovation. In other words, government subsidies can help businesses innovate more effectively to a certain level, which is beneficial to the continued growth of businesses and supports research hypothesis H1. Government subsidies are substantially correlated with the innovation performance of non-state-owned companies in subgroup regression (1), as shown with the regression coefficient of 0.140, which indicates that government subsidies have a major influence on new energy non-state-owned vehicle enterprises. State-owned enterprises usually have good resources, a complete capital chain, and strong overall strength, while non-state-owned enterprises have limited means of obtaining funds. On this basis, government subsidies have more influence on non-state-owned enterprises, so the impact of government subsidies on innovation performance in non-state-owned enterprises is greater than the impact of government subsidies on innovation performance in state-owned enterprises. In subgroup regression (2), government subsidies are significantly and positively related to the innovation performance of large-scale enterprises in new energy vehicles at the 1% level, and of small- and medium-scale enterprises at the 10% level. This suggests that both types of businesses are better at utilizing government funding and have a greater capacity to acquire funding and to use it for innovative performance.

Table 4. Regression results of government subsidies on innovation performance.

	Model 1	**Subgroup Regression (1)**		**Subgroup Regression (2)**	
Variables	**PAT**	**State-Owned**	**Non-State-Owned**	**Large Scale**	**Medium and Small Scale**
SUB	0.112 **	0.019	0.140 ***	0.083 ***	0.123 *
	(0.04)	(0.03)	(0.03)	(0.02)	(0.05)
OIG	−0.066 *	−0.232 ***	−0.021	0.054	−0.172 ***
	(0.03)	(0.02)	(0.07)	(0.06)	(0.04)
GR	0.784 ***	0.611	0.910 ***	−0.026	0.911 ***
	(0.09)	(0.53)	(0.09)	(0.19)	(0.11)
ROA	−0.422	−0.989 **	−0.413	−1.977 ***	0.279
	(0.23)	(0.33)	(0.36)	(0.25)	(0.22)
SIZE	0.320 ***	0.663 ***	0.232 ***	0.422 **	0.428 **
	(0.02)	(0.07)	(0.03)	(0.13)	(0.11)
TOP1	−1.450 ***	−0.922 **	−1.427 ***	−1.135 ***	−1.617 ***
	(0.20)	(0.30)	(0.24)	(0.23)	(0.3)
NAT	0.041			−0.1	0.059
	(0.04)			(0.14)	(0.05)
Constant	−3.764 ***	−9.977 ***	−2.353 **	−5.139	−6.371 **
	(0.72)	(1.65)	(0.88)	(2.78)	(1.71)
Observations	924	238	686	462	462
Number of groups	154	46	119	95	101
FE	YES	YES	YES	YES	YES
F	98.79	1965	294	147.3	768.7
R-squared	0.238	0.333	0.22	0.217	0.274

The ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively, with standard errors in parentheses.

4.3.2. Testing the Relationship between Government Subsidies and R&D Intensity

According to Table 5, the government's subsidies have a 0.004 coefficient on R&D intensity, which is significant at the 1% level. This supports the expected hypothesis H2 that there is a significant positive association between government subsidies and R&D intensity, that is, that government subsidies (SUB) obtained by new energy automotive firms play a part in encouraging R&D intensity (R&D). In subgroup regression (1), the government's subsidies have the same effect on R&D intensity in state-owned and non-state-owned businesses; both effects are significant at the 1% level and have impact coefficients of 0.004. According to these findings, which are consistent with the findings of the benchmark regression, the effect of government subsidies on R&D intensity does not vary depending on the nature of businesses in the new energy vehicle sector.

Table 5. Regression results of government subsidies on R&D intensity.

	Model 2	**Subgroup Regression (1)**		**Subgroup Regression (2)**	
Variables	**R&D**	**State-Owned**	**Non-State-Owned**	**Large Scale**	**Medium and Small Scale**
SUB	0.004 ***	0.004 ***	0.004 ***	0.003 ***	0.004 *
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
OIG	−0.015 ***	−0.010 ***	−0.016 **	−0.010 **	−0.018 ***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GR	0.013 *	−0.003	0.021 **	−0.035 ***	0.040 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ROA	−0.019	−0.024	−0.006	−0.071 ***	−0.001
	(0.02)	(0.02)	(0.02)	(0.01)	(0.03)
SIZE	−0.004	−0.005 *	−0.003	0.006 ***	−0.012
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
TOP1	−0.026 **	−0.055 ***	−0.011	0.006	−0.031 **
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
NAT	−0.003			0.008 ***	−0.009
	(0.00)			(0.00)	(0.01)
Constant	0.066	0.102	0.051	−0.132 ***	0.249
	(0.03)	(0.06)	(0.06)	(0.02)	(0.17)
Observations	924	238	686	462	462
Number of groups	154	46	119	95	101
FE	YES	YES	YES	YES	YES
F	992.5	361.9	22.66	40.42	62.97
R-squared	0.118	0.11	0.122	0.257	0.106

The ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively, with standard errors in parentheses.

4.3.3. The Mediating Effect of R&D Intensity

The new energy automotive business exhibits a positive association between R&D intensity and innovation performance, as demonstrated in Table 6. When R&D intensity increases by 1%, innovation performance increases by 3.566, which means that increasing the R&D intensity of new energy automobile enterprises can effectively improve innovation performance. Additionally, the outcomes of earlier tests demonstrate that government subsidies aid in enhancing the innovation performance and the R&D intensity of businesses. Then, what role does enterprise R&D intensity play in the positive relationship between government subsidies and enterprise innovation performance? By adding the R&D intensity variable, there is a significant positive correlation between government subsidies and innovation performance. When comparing the impact coefficients of the two before and after the government subsidy, it is found that it decreases from 0.112 to 0.098; this indicates that the R&D intensity of the enterprise plays a partial mediating role between the government subsidy and innovation performance. A part of government subsidies indirectly promotes innovation performance through R&D intensity, so the expected hypothesis H3 is verified.

Table 6. Regression of the mechanism of R&D intensity.

	Model 2	Subgroup Regression (1)		Subgroup Regression (2)	
Variables	**PAT**	**State-Owned**	**Non-State-Owned**	**Large Scale**	**Medium and Small Scale**
SUB	0.098 **	0	0.127 **	0.064 **	0.112 *
	(0.03)	(0.02)	(0.03)	(0.02)	(0.05)
R&D	3.566 ***	4.488 **	3.160 ***	5.506 ***	2.588 ***
	(0.47)	(1.4)	(0.39)	(1.36)	(0.42)
OIG	−0.014	−0.185 ***	0.03	0.107	−0.125 **
	(0.03)	(0.03)	(0.07)	(0.05)	(0.04)
GR	0.738 ***	0.623	0.843 ***	0.166	0.807 ***
	(0.09)	(0.52)	(0.09)	(0.21)	(0.11)
ROA	−0.352	−0.881 *	−0.393	−1.588 ***	0.282
	(0.19)	(0.34)	(0.31)	(0.22)	(0.20)
SIZE	0.333 ***	0.684 ***	0.242 ***	0.391**	0.460 ***
	(0.02)	(0.06)	(0.03)	(0.13)	(0.09)
TOP1	−1.356 ***	−0.675 **	−1.392 ***	−1.169 ***	−1.536 ***
	(0.19)	(0.19)	(0.22)	(0.21)	(0.32)
NAT	0.05			−0.146	0.081 *
	(0.04)			(0.15)	(0.03)
Constant	−3.998 ***	−10.433 ***	−2.514 **	−4.413	−7.014 ***
	(0.75)	(1.32)	(0.89)	(2.81)	(1.40)
Observations	924	238	686	462	462
Number of groups	154	46	119	95	101
FE	YES	YES	YES	YES	YES
F	48.92	148.2	97.01	49.74	41.7
R-squared	0.253	0.352	0.232	0.235	0.287

The ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively, with standard errors in parentheses.

4.4. Robustness Testing

To assess the validity of the study's findings, we replace the model with FGLS regression in this study. The specific regression results are shown in Table 7. The coefficient of government subsidies on R&D intensity is 0.004, which still represents a significant positive at the 1% level, according to column 1 of the regression findings. Column 2 of the regression results shows that the coefficient of government subsidies on innovation performance is 0.057, which is still significantly positive at the 1% level. In column 3 of the regression results, the correlation coefficients of government subsidies and R&D intensity on innovation performance are 0.050 and 3.825, respectively, both of which are significantly positive at the 1% level. The empirical findings of the benchmark regression are compatible with this result, as can be observed. And in column 3 of the regression findings, the coefficient of government subsidies on innovation performance falls, suggesting that R&D intensity acts as a mediating factor between government subsidies and innovation performance. Therefore, this paper's conclusions are quite reliable.

Table 7. Robustness test for benchmark regression.

	Model 1	Model 2	Model 3
Variables	**R&D**	**PAT**	**PAT**
SUB	0.004 ***	0.057 ***	0.050 ***
	(0.00)	(0.01)	(0.01)
R&D			3.825 ***
			(0.64)
OIG	−0.008 ***	−0.092 ***	−0.048 *
	(0.00)	(0.03)	(0.03)
GR	−0.007 **	0.503 ***	0.437 ***
	(0.00)	(0.12)	(0.12)
ROA	−0.024***	−0.034	0.076
	(0.01)	(0.18)	(0.17)
SIZE	−0.004 ***	0.492 ***	0.499 ***
	(0.00)	(0.03)	(0.03)
TOP1	−0.026 ***	−0.054	−0.006
	(0.00)	(0.18)	(0.18)
NAT	0.000	−0.013	0.039
	(0.00)	(0.05)	(0.05)
Constant	0.093 ***	−6.944 ***	−7.185 ***
	(0.01)	(0.57)	(0.58)
Observations	924	924	924
Number of ids	154	154	154
Wald	222.5	667.5	651.2

The ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively, with standard errors in parentheses.

5. Discussion

This study examines the relationship between government subsidies, research and development (R&D) intensity, and innovation performance within the context of the new energy automotive industry. On the one hand, it is discovered that government subsidies may greatly enhance business innovation performance by integrating the study of technical innovation theory, market failure theory, and signaling theory. Enterprises are the core subjects of technological innovation decision making, R&D investment, and results transformation. Enterprise R&D and innovation activities' characteristics with public products, and a "market failure" phenomenon, exist. R&D for the new energy automobile industry requires a significant amount of funding; if the private sector is the only source of funding, this will result in a mismatch between R&D revenue and R&D investment, which will eventually put new energy automobile R&D innovation activities on hold. In this context, government subsidies can empower R&D innovation in new energy vehicles. In addition to providing direct financial support for research and development, innovation subsidies have the potential to offer firms supplementary financing. Additionally, it has the potential to transmit favorable indications to external stakeholders via technological evaluation and dynamic regulation. This enables external investors to mitigate potential issues related to adverse selection and moral hazard, therefore enhancing their financial support for enterprise research and development (R&D) and innovation. On the other hand, the heterogeneous performance of new energy vehicle R&D innovation is analyzed in depth through empirical evidence. The research results show that the effect of government subsidies to enhance enterprise innovation performance is more obvious in non-state-owned and large enterprises. This provides practical guidance for the government to support the new energy automobile industry to accurately design innovation subsidy policies.

This study updates the research object, based on the new energy automobile industry, which is different from the previous literature. The existing body of research on the influence of government subsidies on enterprises' innovation performance has primarily concentrated on the new energy sector, as shown by Wu et al. [16], and non-financial listed companies, as demonstrated by Zhang et al. [34]. However, there is a dearth of studies that investigate this relationship within a particular industry. Additionally, regarding research

Hypothesis 1, the effect of government subsidies on the innovation performance of firms with different ownership is not the same. The nature and structure of firms' ownership fundamentally determine their resource allocation and governance structure, making the sensitivity of innovation to government subsidies heterogeneous. According to the research conducted by Wang et al. [25], it was observed that government subsidies had a more significant impact on fostering innovation in private enterprises and central locations. The findings of this paper suggest that government subsidies have a significant positive effect on firms' innovation performance, and this effect is more pronounced in non-state-owned and large firms. Furthermore, about study Hypothesis 3, Xu et al. [30] discovered that internal control serves as a significant mediator in the relationship between government subsidies and innovation performance. The level of internal control has the potential to significantly influence the intensity of investment in research and development. This suggested that R&D investment intensity be chosen as a mediating variable in this paper.

The study in this paper has certain practical value. From a governmental perspective, it is advisable to consider subdividing subsidy categories and dividing the enterprise standards. A comprehensive examination of enterprise R&D transformation capability, specifically the transformation capability of strong, highly motivated R&D firms, to increase subsidies is recommended. Meanwhile, the incentive mechanism and innovation protection system to foster the advancement of innovation are advised. Within the context of a market economy, enterprises are guided by the concept of the "invisible hand" to formulate and implement strategic planning. The implementation of rules and regulations about quality and safety oversight, together with the establishment of market order, are crucial in fostering a conducive market environment for the growth and development of enterprises. For new energy automotive companies, it is important to understand that government subsidies have non-renewable qualities. While using government subsidies to spur innovation, companies should also fortify their sense of crisis to prevent relying too heavily on them. Only by genuinely enhancing the capacity for independent innovation will we be able to expand our development space and market prospects and achieve sustainable growth.

6. Conclusions

In our study, we found that government subsidies can help improve enterprise performance. The government issues funds for enterprises according to relevant policies. On the one hand, it solves the difficulties faced by enterprises in financing their R&D activities. On the other hand, it releases the signals that enterprises' innovation activities are actively carried out, eases the financing problems of enterprises, broadens the channels of enterprises' sources of funds, helps enterprises form a virtuous circle of carrying out R&D activities, and then increases the innovation performance of enterprises. Government subsidies have an obvious promotion effect on R&D intensity. The R&D activities of enterprises are accompanied by expenditures with high risk and high uncertainty. The funds brought with government subsidies can improve the financial situation of small-scale enterprises, can help large-scale enterprises to increase shareholder confidence, and can help to enhance the intensity of R&D, which in turn improves innovation performance. Meanwhile, R&D intensity can directly or indirectly affect the innovation performance of the new energy automobile industry. R&D intensity plays a mediating effect between government subsidies and innovation performance. The purpose of government subsidies is to strengthen enterprises to carry out innovative activities; enterprises can enhance R&D intensity through government subsidies to improve innovation performance and can help realize sustainable development. However, government subsidies are a dynamic and ever-changing process. This paper is based on an empirical analysis and lacks a dynamic analysis of the interaction between government innovation subsidies and enterprise R&D innovation. The distribution of innovation resources is determined by the government based on its criteria. Enterprises thereafter construct specialized innovation plans on the decisions made by policy departments, sometimes overlooking the importance of considering their developmental circumstances. This phenomenon may result in a divergence between technical advancements and market demands, as well as the prevalence of mundane and repeated research and development (R&D) and innovation endeavors undertaken by businesses. In future investigations, it is vital to do a study from this particular standpoint.

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