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Influence of Technological Innovation on Sustainable Development of New Energy Enterprises

-- Research on the Mediating Effect of Government Subsidies

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Abstract

Technological innovation of new energy industry plays an important role in accelerating China's structural transformation and improving its comprehensive national power, making the government give it more attention and support. In this paper, relevant panel data of the new energy industry from 2010-2020 are selected for compilation and analysis, and the mediating effect model is used to study the influence of technological innovation on sustainable development of new energy enterprises and government subsidies, as well as the mediating effect of government subsidies, respectively. The empirical results show that :(1) The density of technical personnel and the level of technical patents are significantly positively correlated with the sustainable development of new energy enterprises ;(2) R&D investment intensity and technical patent level are significantly positively correlated with government subsidies ;(3) The level of government subsidies has mediating effect between R&D investment intensity and sustainable development of new energy enterprises, and between the level of technical patents and sustainable development of new energy enterprises.

Keywords

New Energy Enterprises; Technological Innovation; Government Subsidies; Sustainable Development; Mediating Effect.

CLC number

F204; F224; F124.3

1. Introduction

The 14th Five-Year Plan and the vision of 2035 emphasize that we should grasp the core essence of sustainable innovation in the overall situation of China 's modernization construction and advocate the self-independence and self-reliance of soft power of science and technology in the national development strategy. It is of great strategic significance to highly examine the path of sustainable economic and social development and accelerate the scientific and technological innovation of new energy industry. However, technological innovation investment is lagging and risky, and thus the government has issued a series of incentive and support policies to help enterprises develop sustainably. According to the statistical data of Academia Sinica, the market size of China ' s new energy industry from 2018 to 2020 is 882.3 billion yuan, 907.5 billion yuan and 933.5 billion yuan, respectively. In the face of today's huge

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and complex market, the competitive pressure is increasing day by day. How to maintain sustainable development capability in a market with huge operating risks is an urgent problem for energy enterprises.

Zhang Zongqing makes a general analysis of technological innovation, and realizes that technological innovation plays an important role in the sustainable development of enterprises in the era of knowledge economy[1].Xu Xin et al. decompose technological innovation, and find that the more R&D investment, the enterprise value and operating performance will also improve. At the same time, different quality patents will also increase enterprise performance, and the higher the degree of innovation, the more obvious the invention patents improve enterprise performance[3].Cheng Hua et al. added government science and technology subsidies to explore the relationship between government science and technology subsidies and enterprise R&D investment. The results show that the stronger the enterprise R&D investment is, the better the incentive effect of government science and technology subsidies is[6].From the above research, it can be seen that the more enterprises invest in R&D and holds higher quality patents, the higher government incentives and business performance it can obtain. However, Zhang Xinrong et al. believed that government subsidies can stimulate enterprises to invest in R&D, thereby increasing their business performance[8]. However, few scholars have studied government subsidies as an intermediary variable. Therefore, this paper uses the mediating effect to analyze the impact of technological innovation on the sustainable development of new energy enterprises through government subsidies.

This paper selects the relevant panel data of the new energy industry from 2010 to 2020 for empirical test, and discusses the mediating effect of government subsidies by analyzing the relationship between technological innovation, government subsidies and sustainable development of enterprises. It is expected to draw conclusions that are conducive to the sustainable development of new energy enterprises and the formulation of macro-control policies at the national strategic level.

2. Research Hypothesis

2.1. Research Hypothesis of Technological Innovation on Sustainable Development of Enterprises

Deng Xidong et al. empirically found that R&D investment has a positive impact on the value of high-tech enterprises, and part of it comes from the effect that indirectly affects investor confidence[5].The sustainable development ability of enterprises depends on the profitability of continuous growth, namely, value creation ability. Du Xingqiang et al. found that the role of R&D investment in improving corporate performance is continuous and stable[4].Enterprise performance is the representative factor of enterprise sustainable development ability. Therefore, Hypothesis H1a is proposed: R&D investment intensity is positively correlated with the sustainable development of new energy enterprises.

Chen Xiaohong et al. found that the investment in technical personnel, the investment in R&D technological transformation and the performance of innovation and transformation are directly proportional[2].Innovation transformation is divided into product innovation and technological innovation, both of which are prerequisites for enterprises to achieve sustainable development. So put forward the hypothesis H1b : technical personnel density is positively related to the sustainable development of new energy enterprises.

Xu Xin et al. found that patents will contribute to corporate performance, but this influence is related to the quality of patents. The higher the innovation degree of invention patents is, the more obvious the improvement of corporate performance is[3].The intellectual property advantages of enterprises mainly include the quantity and quality of patents, and the number of patents held can reflect the ability of technological innovation, enhance the core

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competitiveness of enterprises, so as to create profits for enterprises to sustainable development. Therefore, the hypothesis H1c is proposed: the level of technical patents has a positive correlation with the sustainable development of new energy enterprises.

2.2. Research Hypothesis of Technological Innovation on Government Subsidy

Cheng Hua et al. found that the stronger the R&D investment of enterprises is, the better the incentive effect of government science and technology funding is[6].The greater the intensity of R&D investment of enterprises is, the more the amount of financing is needed and the higher the financial risk is borne, and the incentive role that the government needs to play is also greater. Therefore, Hypothesis H2a is proposed : R&D investment intensity has a positive correlation with the government subsidy level of new energy enterprises.

Zheng Yuelong et al. believed that regardless of whether they were in the dominant position, the technological level of enterprises had a great impact on the relevant parameters of government subsidies[7]. Both technical personnel and technical patents can reflect the technical level of enterprises, and they explain the high and low technical level from the perspective of quality and quantity respectively. Through the research and analysis of scholars, it can be known that the technical level has a great impact on government subsidies. Therefore, this paper decides to divide it into two dimensions to study the relationship between technological level and government subsidies in more detail. That is, the hypothesis H2b is proposed: the density of technical personnel is positively correlated with the level of government subsidies for new energy enterprises; Suppose H2c: technology patent level is positively correlated with government subsidies for new energy enterprises.

2.3. Research Hypothesis of the Mediating Effect of Government Subsidies

Based on the development trend of new energy industry, it can be predicted that government subsidies will also have a mediating effect between technological innovation and sustainable development in the new energy industry. This paper decomposes technological innovation: R&D investment, technical personnel and patent level. In order to fill the blank of the unexplored field, the following research hypotheses are proposed: H3a : the level of government subsidies plays an intermediary role between R&D investment intensity and sustainable development of new energy enterprises; H3b: The level of government subsidies plays a mediating role between the density of technical personnel and the sustainable development of new energy enterprises ;H3c: The level of government subsidies plays an intermediary role between the level of technology patents and the sustainable development of new energy enterprises.

3. Research Design

3.1. Variable Design

The explained variable in this paper is the sustainable development ability of enterprises, and the selected index is the sustainable growth rate. Sustainable growth ability reflects the internal growth ability of enterprises. The decisive factors include enterprise management efficiency, capital structure and profit distribution policy. This financial index provides a reference standard for the development of enterprises to ensure the sustainable development of enterprises. The level of government subsidies is selected as a mediator variable to show the government's support for new energy enterprises. With the integration of the economic world and the rapid development of high-tech, R&D investment intensity has become an important factor to stimulate enterprise innovation vitality and enhance enterprise science and technology innovation ability. As the carrier of technological innovation, technological patents reflect the ability and competitiveness of enterprises to apply knowledge for innovation. Technological innovation is inseparable from the efforts of enterprise technical professionals.

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Therefore, this paper selects R&D investment intensity, technical personnel density and technical patent level as explanatory variables.

There are many other factors that affect the sustainable development of enterprises. In order to be rigorous and scientific, this paper selects capital structure and cash capacity as control variables.

Table 1 Variable description

Classification	Variable	Variable Symbol	Variable Meaning
Explained variable	Sustainable Growth	SGR	(ROE×Profit Retention Rate)/(1-ROE×Profit Retention Rate)
Mediator variable	Government Subsidy Level	SUB	Government Subsidies/Operating Income
Explanatory variables	R&D Investment Intensity	XDD	R&D Expenditure/Operating Income
	Technical Personnel Density	TPD	Technical Personnel/Total Staff
	Technical Patent Level	TPL	Number of Patent Applications in the Year
Control variables	Capital Structure	ALR	Total Indebtedness/Total Assets
	Cash Capacity	CASH	Net Cash Flow from Operating Activities/Operating Income

3.2. Model Construction

In order to verify the relationship between technological innovation and sustainable development of new energy enterprises and government subsidies, models(1) and(2) are constructed. In model (1), the government subsidy level is added to obtain model (3) to test whether the government subsidy level plays an intermediary role between technological innovation and sustainable development of new energy enterprises. By testing whether the coefficients β_1 ,β_2, β_3 ,γ_1 ,γ_2 ,γ_3 ,ω_1, ω_2, ω_3 and $\omega_4$are significant, we can verify whether the level of government subsidies exist mediating effect. While coefficients β_1 ,β_2 and β_3 represent the effects of explanatory variables ' R&D investment intensity, technical personnel density and technical patent level on the explained variable ' s sustainable growth rate, respectively; The coefficientsγ_1, γ_2 and γ_3 represent the effects of the explanatory variables R&D investment intensity, technical personnel density and technology patent level on the intermediary variable government subsidy level respectively; Coefficient ω_4 represents the impact of the intermediary variable government subsidy level on the explained variable 's sustainable growth rate after controlling the independent variable R&D investment intensity, technical personnel density and technical patent level ;The coefficients ω_1, ω_2 and ω_3 represent the direct effects of the independent variables R&D investment intensity, technical personnel density and technical patent level on the sustainable growth rate of the explained variable after controlling the level of government subsidy as the intermediary variable. The product of coefficients γ_1, γ_2 and γ_3 with d respectively represents the indirect effect of the model, namely the mediating effect.

$$SGR_{i,t} = C + \beta_1 XDD_{it} + \beta_2 TPD_{it} + \beta_3 TPL_{it} + \beta_4 ALR_{it} + \beta_5 CASH_{it} + \varepsilon_{it} \quad (1)$$

$$SUB_{i,t} = \alpha + \gamma_1 XDD_{it} + \gamma_2 TPD_{it} + \gamma_3 TPL_{it} + \gamma_4 ALR_{it} + \gamma_5 CASH_{it} + \mu_{it} \quad (2)$$

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$$SGR_{i,t} = \delta + \omega_1 XDD_{it} + \omega_2 TPD_{it} + \omega_3 TPL_{it} + \omega_4 SUB_{it} + \omega_5 ALR_{it} + \omega_6 CASH_{it} + \tau_{it} \quad (3)$$

In the formula, i denotes the individual enterprise being studied, i = 1,2,3... 147 ;t represents year, t = 2010, 2011, 2012,..., 2020 ;α is a constant, ε_{it}, μ_{it} and τ_{it} are disturbance terms.

3.3. Sample Selection and Data Source

This paper selects the data from 2010 to 2020 of new energy companies listed on A-shares in Shanghai and Shenzhen as the sample data. Exclude all enterprises rated ST and *ST, as well as sample data with missing or abnormal data such as enterprise financial data, proportion of technical personnel, technical patent level, and government subsidies. After screening, 147 A-share listed companies in the new energy industry were obtained as the research objects of this paper, and 1,365 sample data were used as the total sample size of this paper. The research data in this paper came from CNRDS, and software such as EXCEL and STATA16 were used for data processing.

4. Empirical Test

4.1. Descriptive Statistics

Table 2 shows the basic situation of enterprises in China's new energy industry from 2010 to 2020. The basic situation indicators include: the endogenous growth index sustainable growth rate of sustainable development ability of enterprises, and the R&D investment intensity, technical personnel density and technical patent level of technological innovation ability of enterprises. In addition, it also includes the level of government subsidies, capital structure and cash ability.

Table 2. Descriptive statistics

Variable	Variable Description	Mean Value	Standard Deviation	Minimum Value	Maximum Value
SGR	Sustainable Growth Rate	0.5696	1.699	-7.4225	50.4051
SUB	Government Subsidy Level	0.0074	0.0166	0	0.3772
XDD	R&D Investment Intensity	0.0382	0.0343	0.0001	0.4672
TPD	Technical Personnel Density	0.1415	0.0911	0.0001	0.4712
TPL	Technical Patent Level	14.3223	73.6111	0	1363
ALR	Capital Structure	0.4949	0.2016	0.0395	1.0444
CASH	Cash Capacity	0.4949	0.2016	0.0395	1.0444

It can be seen from the table that among the indicators of sustainable development ability of new energy enterprises in China, the average sustainable growth rate of profit retention growth only through the company's own operating profits is 0.5696%, and the standard deviation is 1.699%.The endogenous growth ability of the new energy industry often depends on the R&D ability of enterprises. Since the life cycle of listed companies is in the growth or maturity stage, there is little difference in the endogenous growth ability, but the development of some enterprises still needs the help of external forces, such as government subsidies. The minimum value of sustainable growth rate is −7.4225 %, and the maximum value is 50.4051 %, indicating

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that there is a large gap in the expansion rate of value maximization among enterprises in the new energy industry, which reflects the advantages and disadvantages of management ability and the level of technological innovation ability among new energy enterprises. By observing other indicators of new energy enterprises, it is found that the minimum value of technology patent level and government subsidy level is 0, indicating that there are still many enterprises only focus on short-term benefits, introduce external advanced technologies and equipment, and do not have key core technologies; In addition, the government subsidy policy has a low degree of adaptation to new energy companies, and some companies do not enjoy relevant preferential government subsidies.

4.2. Correlation Analysis

Table 3. Correlation coefficient between variables

Variable	SGR	SUB	XDD	TPD	TPL	ALR	CASH
SGR	1						
SUB	-0.0334	1					
XDD	0.0109	0.3558***	1				
TPD	0.0587	0.0451	0.4164***	1			
TPL	0.0628**	-0.0009	0.1014***	0.0611	1		
ALR	0.0209	-0.0650**	-0.1443***	-0.0660*	0.0763***	1	
CASH	0.0115	0.1022***	-0.1809***	-0.2742***	-0.0390	0.1157***	1

Note: * * *. At the 0.01 level, the correlation is significant; **. At the 0.05 level, the correlation is significant; *. At the 0.1 level, the correlation is significant

The sustainable growth rate is significantly positively correlated with the level of technical patents, and the intensity of R&D investment is significantly positively correlated with the density of technical personnel, the level of technical patents and the level of government subsidies. Overall, the correlation coefficient between variables is not high, and there is no substitution problem between variables. In addition, in the control variables, capital structure is significantly negatively correlated with the level of government subsidies, and cash capacity is significantly positively correlated with the level of government subsidies.

Before the multiple linear regression analysis, in order to test whether there is a multicollinearity problem between the respective variables, the independent variables such as the government subsidy level and R&D investment intensity of the research object and the sustainable development of the dependent variable were tested for collinearity. The correlation coefficient of is acceptable, there is no multicollinearity problem, and the variables can be regressed.

4.3. Regression Analysis

Table 4. Regression analysis results

Variable	Variable Description	Model1 (SGR)	Model2 (SUB)	Model3 (SGR)
SUB	Government Subsidy Level			0.022*
XDD	R&D Investment Intensity	-0.384	0.258*	0.087
TPD	Technical Personnel Density	0.879**	-0.024	0.835**
TPL	Technical Patent Level	0.002**	0.191*	0.002*
ALR	Capital Structure	-0.198	0.004	-0.19

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CASH	Cash Capacity	0.304*	0.015***	0.332**
C	Constants	0.534***	-0.005	0.524***

Note: * * *. At the 0.01 level, the correlation is significant; **. At the 0.05 level, the correlation is significant; *. At the 0.1 level, the correlation is significant

4.3.1. Influence of Technological Innovation on Sustainable Development of Enterprises

The regression analysis results from Model 1 show that the density of technical personnel in new energy companies is significantly positively correlated with their sustainable development, that is, the research hypothesis H1b is established: the greater the proportion of technical personnel in new energy companies to all employees, the stronger the sustainable development capability of the company. At the same time, the more new energy enterprises apply for technical patents, the stronger the sustainable development ability of enterprises, that is, the research hypothesis H1c holds. However, the research object's R&D investment intensity has no significant negative impact on its sustainable development, that is, the research hypothesis H1a is not established. The reason is that the investment funds needed for research and development of new energy enterprises are huge and risk-taking is high, so enterprises need to reserve strong capital strength to support. It is difficult for ordinary small and medium-sized enterprises and even large enterprises to maintain energy technology research and development with a long payback period; Secondly, many enterprises blind investment, lack of preventive control, such as prior research feasibility analysis, resulting in capital chain problems affecting the operation and development of enterprises; Finally, R&D investment requires sufficient funds. A good financing environment depends on the macroeconomic background. The current energy industry is in the stage of low-carbon transformation, the future trend is not clear enough, and external investors are not active enough, which adversely restricts the development process of enterprises.

4.3.2. Influence of Technological Innovation on Government Subsidy Level

The results of regression analysis from model 2 show that the intensity of R&D investment of new energy enterprises is positively correlated with the level of government subsidies, that is, the research hypothesis H2a is established : the more R&D investment of new energy enterprises, the more government subsidies they get. At the same time, when new energy companies apply for more technology patents, the companies will receive more government subsidies, that is, the research hypothesis H2c is established. The density of technical personnel of the research object has no significant negative impact on the level of government subsidies, that is, the research hypothesis H2b does not hold. On the one hand, for government support or preferential subsidies, the original intention is to improve the innovation ability of enterprises and increase the core competitiveness, and small and medium-sized new energy enterprises are the main support objects. Therefore, energy enterprises with a large proportion of technical personnel are less supported by government subsidies than those with a small proportion. On the other hand, based on the rational allocation of resources, government subsidies are correspondingly reduced for enterprises with a large proportion of technical personnel to prevent enterprises from wasting resources and slack.

4.3.3. The Mediating Effect of Government Subsidies

Combined with the regression analysis results of model 1 and model 2, the R&D investment intensity of new energy enterprises has a significant positive impact on the level of government subsidies, while the R&D investment intensity has no significant impact on its sustainable development, indicating that the level of government subsidies has a complete mediating effect on the R&D investment intensity and the sustainable growth of new energy enterprises. That is, the research hypothesis H3a is established: the larger the amount of R&D investment of new energy enterprises, the greater the government subsidies to them, and then help the

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sustainable development of enterprises. At the same time, the level of technological patents of new energy enterprises is significantly positively correlated with their sustainable growth, and the level of technological patents also has a significantly positive impact on the level of government subsidies, which indirectly indicates that the more new energy enterprises apply for technological patents, the more financial subsidies they will receive from the government, so as to promote the sustainable development of enterprises, that is, the research hypothesis H3c is partially established. Since the technical personnel density of new energy enterprises has no significant negative impact on their government subsidies, the research hypothesis H3b does not hold.

5. Conclusion and Suggestion

5.1. Conclusion

Through the above research, some of the hypotheses proposed in this paper have been confirmed, and the specific research conclusions are as follows:

(1)The density of technical personnel and the level of technical patents have a positive impact on the sustainable development of new energy enterprises.①The density of technical personnel is significantly positively correlated with the sustainable development of new energy enterprises (H1b). It is believed that innovation is an important way for new energy enterprises to remain invincible in the fierce market competition, and the core and main body of innovation is technical personnel. Therefore, in order to innovate and develop, enterprises must pay attention to the excavation and cultivation of technical talents.②The level of technical patents has a significant positive correlation with the sustainable development of new energy enterprises (H1c). It is believed that if enterprises want their own products or technologies to be unique in the market, they need to apply for patents in time for their inventions and creations, form legal protection barriers, ensure enterprises ' investment in technology and improve their core competitiveness. In addition, consumers tend to prefer brands with independent intellectual property rights. The improvement of technology patent level contributes to market promotion, brings economic growth to enterprises and promotes sustainable development of enterprises.

(2)R&D investment intensity and technical patent level have a positive impact on government subsidies.①The intensity of R&D investment has a significantly positive correlation with the level of government subsidies (H2a). The greater the R&D investment intensity of enterprises is, the greater the financing risk and recovery cycle they face. Therefore, the lifting of the financial crisis needs more government macro-control, such as government subsidies, which can reduce the R&D risk of enterprises and maintain the enthusiasm of enterprises for R&D investment.②The level of technical patents is significantly positively correlated with the level of government subsidies (H2c). For a long time, the state encourages technological innovation in enterprises, and patent has become a key judgment basis in project special evaluation and high-tech enterprise evaluation linked with government preferential policies.

(3)The level of government subsidies has mediating effect between R&D investment intensity and enterprise sustainable development, and between technology patent level and enterprise sustainable development.①The level of government subsidies has a mediating effect on the intensity of R&D investment and the sustainable development of enterprises (H3a). The amount of R&D investment determines the development of enterprise science and technology level, so many new energy enterprises are strengthening scientific and technological innovation. At the same time, our government strongly supports the innovation activities of enterprises, and produces incentive effects by subsidizing R&D activities of enterprises. Therefore, it will also affect enterprises to continuously improve their management ability, and then enhance their growth ability.②The level of government subsidies has partial mediating effect on the

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level of technology patents and sustainable development of enterprises (H3c). In order to encourage and promote scientific and technological innovation, the state has formulated patent subsidy policies, such as enterprise technological transformation plans. Enterprises obtain government funding through the holding of technical patents, which reduces the cost and risk of technological innovation of science and technology enterprises, and technical patents can buffer the financing difficulty to a certain extent. At the same time, high-tech enterprises will also enjoy the corresponding preferential tax policies based on the advantages of patents, which will help the long-term development of enterprises.

5.2. Suggestion

In order to promote the sustainable development of new energy enterprises, enterprises should continue to maintain technological innovation and increase government support. According to the situation of the new energy industry and the regression analysis results, the following suggestions are put forward from two dimensions: inside the enterprise and outside the market:

(1)Internal environmental perspective. Firstly, new energy enterprises should pay attention to the introduction and construction of technical talents. Technical personnel are the promoters of technological innovation and the key factor for the sustainable development of high-tech enterprises. Secondly, new energy enterprises should declare patents timely. Enterprises with independent intellectual property rights are more likely to gain the favor of consumers and increase the brand value of enterprises. In addition, as a requirement for the evaluation of high-tech enterprises, patents can obtain the corresponding subsidy policies of the government, which is conducive to the long-term development of enterprises. Finally, new energy enterprises should increase R&D investment. R&D investment to improve their technical level and core competitiveness at the same time, can obtain government subsidies, reduce enterprise financial risk.

(2)External environment. Government departments need to improve the new energy security system and incentive mechanism. In view of the problems existing in the industrial development, establish and improve the corresponding laws and regulations, standardize enterprise management behavior, maintain a good market environment. Technological innovation positive enterprises, should give more preferential policy support, but also need to pay attention to excessive dependence on government subsidies and do not pay attention to their own strength. In addition, countries should develop new energy industry standards, such as technical standards. Increasing the entry barriers of the new energy industry, reducing the blind expansion of downstream enterprises, and stabilizing the industrial chain end also enable enterprises to have a deeper understanding of market demand, avoid being interfered by the external environment, and affect corporate strategic decisions when conducting technological innovation venture capital.

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