An Empirical Test on Whether Policy Incentives Can Improve the Technological Innovation Level of China's New Energy Industry Under the Goal of "Double Carbon"

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Abstract. The new energy industry is of great significance for national industrial security and energy security, and the level of technological innovation determines the international competitiveness of the new energy industry. This paper takes 105 Shanghai and Shenzhen A-share new energy listed companies in China from 2016 to 2021 as the research object, analyzes whether government policies effectively promote the overall technological innovation level of the new energy industry, and explores the sensitivity of upstream, midstream and downstream enterprises to policy incentives. The results show that there are differences in innovation efficiency, innovation willingness and innovation ability in different positions of industrial development. Tax incentives favor upstream and midstream firms for technological innovation, while government subsidies encourage R&D investment for all firms. It also suggested that the future new energy industry policy should be measured by innovation efficiency, design more accurate policy means, and establish differentiated policies for different positions in the industrial chain.

Keywords: carbon peaking and carbon neutrality goals; technological innovation; tax benefits; government subsidies; new energy industry

1 Introduction

In the process of continuous global economic growth and modernization, the traditional energy model relying on fossil fuels has revealed its limitations of sustainability, which has spawned an urgent need for energy structure transformation. In October 2010, the Chinese government issued the Decision of The State Council on Accelerating the Cultivation and Development of Strategic Emerging Industries, which identified the new energy industry as a key growth area [1]. As macro-policy tools, financial incentives and government subsidies effectively guide technological innovation and enhance the core competitiveness of enterprises. Using data from A-share listed companies in Shanghai and Shenzhen from 2019 to 2023, this research plan analyzes the impact of government subsidies and tax incentives on technological innovation of new energy enterprises and evaluates the effectiveness of government incentives.

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2 Literature Review

2.1 Technological innovation of new energy industry

New energy industry as a high-tech industry, the core of its development lies in technological innovation. At present, domestic and foreign scholars mainly study the technological innovation of the new energy industry from three perspectives: government policy, innovation environment and market structure [2]. Liang Xiaoying found that market driving significantly promoted the innovation input of listed companies in China's new energy vehicle industry, and the regulating effect of market competition enhanced the government's support for technological innovation in the new energy industry [3]. Using patent data from 2000 to 2013, Guo found that public policy played an important role in new energy patent applications, and that different types of policy tools had different impacts on technological innovation in the new energy industry. Zhang Genming [4] discussed the behavior mechanism of technological innovation in the new energy industry, providing a new perspective to explain the lack of innovation motivation within enterprises.

2.2 The impact of fiscal and tax policies on the innovation effect of enterprises.

Related research has mainly formed the following four different views. First of all, fiscal and tax policies have a significant incentive effect on enterprise innovation activities. For example, the empirical research results of Claussen and Minniti [5] show that government subsidies can provide incentives for enterprises to invest in R&D, especially for enterprises with low technology level. Second, the effect of government subsidies on technological innovation is not significant. For example, Yu [6] believes that government subsidies have no obvious incentive effect on technological innovation of enterprises, but have a negative impact on technological innovation of enterprises. The inconsistent findings suggest that tax incentives and government subsidies are not the only way to encourage technological innovation, but are also influenced by incentive goals, regulatory intensity, and local market conditions.

2.3 The impact of fiscal and tax policies on R&D investment of new energy enterprises

Dai Chen believes that tax incentives have a strong incentive effect on R&D investment, while government subsidies are more advantageous in terms of specific application and response time. Shang Hongtao introduced risk taking as an intermediary variable to study the impact of government subsidies on enterprise technological innovation, and found that government subsidies can promote enterprise technological innovation by improving the level of enterprise risk taking, and have lagging incentive effect on both the quantity and quality of enterprise innovation, which is particularly significant in manufacturing and small-scale private technology enterprises.

3 Research Design

3.1 Theoretical mechanism and research hypothesis

As a new type of clean industry, the new energy industry has attracted much attention, and its technological innovation activities have typical positive externalities. Tax incentives and government subsidies can improve private returns on firms' technological innovation investments and correct market failures, thus promoting firms to increase capital investment in technological innovation. Therefore, this paper proposes hypothesis 1: Tax incentives and government subsidies can encourage enterprises to increase innovation investment and promote technological innovation. Due to the high cost and high risk of technological innovation, enterprises tend to pay too much attention to the short-term return of investment while ignoring the long-term benefits brought by technological innovation, resulting in risk externalization and uncertainty of the impact on the output and efficiency of technological innovation. Therefore, this paper puts forward research hypothesis 2: tax incentives and government subsidies have different incentive effects on enterprise innovation input, innovation output and innovation efficiency.

3.2 Sample selection and data sources

This study takes listed new energy companies in China's Shanghai and Shenzhen A-share markets from 2019 to 2023 as the object, using enterprise data as sample data. In order to reduce the inaccuracy of empirical results caused by abnormal data, the sample data were processed: first, ST and *ST listed companies were excluded; Secondly, the listed companies with missing data are excluded. Once again, listed companies with abnormal financial conditions were excluded. The sample data came from the CSMAR database and the annual reports of listed companies, and the data such as the number of patent applications and research and development investment were manually collated. This study mainly uses Excel and Stata16.0 statistical analysis software for data processing and empirical analysis. At the same time, according to the proportion of the main business of the new energy business of the listed companies, the position of the new energy listed companies in the industrial chain is classified, and the sample enterprises are divided into three groups: upstream, midstream and downstream.

3.3 Variable selection and model setting

(1) Variable selection. In this paper, the explained variables are R&D investment (RD) and Patent application number (Patent), and the explanatory variables are Tax incentives (Tax) and government subsidies (Sub). The explanatory variables are measured in terms of tax incentives and government subsidies received by firms. The tax incentives enjoyed by enterprises can be divided into direct incentives and indirect incentives, but considering the factors such as capital and time, the variable value of tax incentives is selected as "the return of various taxes received" in the annual report of enterprises. "Government subsidies received" in the annual report of the enterprise is selected as the variable value of government subsidies. Based on the existing research, the enterprise Size (Size), current ratio (CA), asset-liability ratio (ZCFZL), total operating cost (YYZCB) and main business income (ZYYWSR) are selected as control variables, and the annual variable (YEAR) and property right nature (SOE) are taken as virtual variables. The above indicator data are obtained from the annual reports of listed companies. The definition of each variable is shown in Table 1.

Table 1. Variable definition.

Variable type	Variable name	Variable symbol	Variable calculation method
Explained variable	Enterprise R&D investment	lnRD	Take the natural logarithm of R&D expenditure plus 1
	Number of patent applications	Patent	Total number of annual applications for invention patents utility model patents and design patents
Explanatory variable	Tax incentives	lnTax	Take the natural logarithm of each tax refund plus 1
	Government subsidy	lnSub	Take the government grant plus the natural log of 1
Control variable	Enterprise scale	lnSize	Take the natural logarithm of the total assets of the business
	Current ratio	CA	Current assets/total assets
	Asset-liability ratio	ZCFZL	Total liabilities/total assets
	Total operating cost	lnYYZCB	Take the natural logarithm of total operating costs
	Income from main business	lnZYYWSR	Take the natural logarithm of the main business revenue
Dummy variable	Annual variable	YEAR	Annual dummy variable
	Property right nature	SOE	State-owned enterprises are 1, otherwise 0

(2) Model setting.

After constructing multiple regression model and data processing, this paper uses Stata16.0 software to empirically analyze the incentive effect of tax incentives and government subsidies on enterprise technological innovation. This paper directly performs the estimation of fixed effects and random effects of panel data. In order to more accurately test the influence of explanatory variables on the explained variables, a bidirectional fixed effect model was selected with the help of LM test and Hausman test. The specific form of the model is as follows:

$$Y_{it} = \alpha_0 + \sum\alpha_i X_{it} + \sum\beta_i Cu_{it} + \sum\gamma_i Treat_{it} + \varepsilon_{it} \quad (1)$$

In model (1), Y_{it} is the explained variable, representing the R&D investment and the number of patent applications, and its value is the focus of this paper. X_{it} is the explanatory variable. If i=1, X_{it} is X_1 tax incentives; if i=2, X_{it} is X_2 government subsidies; α_i is the main parameter to be estimated. If α_i is significantly positive, it indicates that tax incentives and government subsidies have incentive effects on enterprise technological innovation. Cu_{it} is the control variable. $Treat_{it}$ as dummy variable; ε_{it} is the error term.

3.4 Descriptive Statistical analysis of variables

As can be seen from Table 2, the minimum value of lnRD is 0.000, the maximum is 13.876, and the standard deviation is 2.508, indicating that different enterprises have great differences in technological innovation investment. The minimum number of enterprise Patent applications (patents) is 1.000, Maximum value is 2243.000, the standard deviation is

191.780, indicating that different enterprises also have great differences in technological innovation output. The mean value of lnTax is 7.221 and the standard deviation is 2.934, indicating that different enterprises enjoy different tax incentives. The mean value of government subsidies (lnSub) is 7.549, and the standard deviation is 1.742, indicating that different enterprises enjoy great differences in government subsidies. On this basis, Stata16.0 software is used to standardize the variables, so that the mean value is 0 and the variance is 1, which can solve the problems caused by different dimensions such as asset-liability ratio.

Table 2. Descriptive statistical results of variables.

Variables	Observed value	Mean value	Median	Standard deviation	Minimum value	Maximum value
ln*RD*	696	8.771	9.207	2.508	0.000	13.876
Patent	696	58.670	14.500	191.780	1.000	2243.000
ln*Tax*	696	7.221	7.875	2.934	0.000	13.371
ln*Sub*	696	7.549	7.643	1.742	0.000	12.330
ln*Size*	696	13.829	13.670	1.392	9.240	17.528
CA	696	1.669	1.326	2.131	0.060	40.131
ZCFZL	696	52.032	51.820	17.663	2.710	98.860
ln*YYZCB*	696	12.976	12.856	1.340	9.888	16.878
ln*ZYYWSR*	696	13.019	12.877	1.364	9.554	16.887
YEAR	696	14.914	12.000	7.304	1.000	29.000
SOE	696	0.500	0.000	0.500	0.000	1.000

4 Empirical Analysis

4.1 Baseline regression results

In this paper, model (1) is used to empirically test the incentive effect of tax incentives and government subsidies on enterprise technological innovation, and the results are shown in Table 3. As can be seen from column (a) of Table 3, the estimated coefficient values of lnTax and lnSub are 0.176 and 0.408 respectively, and both are significant at 1% level, indicating that tax incentives and government subsidies can promote enterprises to increase R&D investment. As can be seen from column (b), the estimated coefficient of lnTax is 5.677 and is significant at 5% level, and the estimated coefficient of lnSub is 17.878 and is significant at 1% level, indicating that tax incentives and government subsidies have significant incentive effects on the number of patent applications of enterprises. Tax incentives and government subsidies have a significant incentive effect on technological innovation input and the number of patent applications of enterprises. After enterprises obtain government subsidies and increase R&D input, they can effectively transform it into substantial technological innovation output and improve technological innovation ability. In conclusion, hypothesis 1 is verified.

Table 3. Regression results of bidirectional fixed effect model.

Variables	ln*RD* (a)	*Patent* (b)	*CX* (c)
ln*Tax*	0.17*** (5.91)	5.677** (2.16)	0.563** (1.98)
ln*Sub*	0.408*** (7.25)	17.878*** (2.436)	2.776*** (4.81)
ln*Size*	-0.919*** (-7.10)	-0.459 (-0.04)	-0.633 (-0.55)
CA	-0.186 (-1.01)	-1.636 (-0.46)	-0.067 (-0.20)
ZCFZL	-0.019*** (-3.28)	-0.569 (-1.14)	-0.018 (-0.37)
ln*YYZCB*	1.156*** (2.60)	52.179 (1.13)	4.218 (1.15)
ln*ZYYWSR*	0.114 (0.26)	-8.223 (-0.21)	-0.359 (-0.10)
YEAR	-0.057*** (-4.72)	-3.95*** (-3.68)	-0.363*** (-3.32)
SOE	-0.260 (-1.54)	-27.288* (-1.83)	-3.221** (-2.14)
Constant	2.663*** (3.07)	-576.955*** (-7.54)	-52.128*** (-6.86)
Observations	696.000	696.000	630.000
R-squared	0.800	0.934	0.200

Note: ***, ** and * are significant at the level of 1%, 5% and 10% respectively, and the numbers in brackets are T-values.

4.2 Heterogeneity analysis of enterprise innovation efficiency

Utilizing the data from 106 selected enterprises, this study employs the logarithm of companies' R&D expenditures and measures innovation efficiency through the ratio of patent applications to the cumulative R&D spending over the previous two years. The average innovation efficiency across the six-year period from 2016 to 2021 is used as a benchmark to assess the variations in technological innovation efficiency among enterprises in the new energy industry's midstream and downstream sectors. The data sources include annual reports of listed companies and information from the Wind database. Figures 1, 2, and 3 illustrate the top ten enterprises in terms of average innovation efficiency at the upstream, midstream, and downstream levels from 2016 to 2021, respectively. Figure 1 indicates that, among upstream enterprises, Leading Intelligence exhibits the highest average innovation efficiency at 36.08%, while Disen Shares presents the lowest efficiency at 2.48%, signifying a considerable gap in innovation efficiency among upstream enterprises. Figure 2 reveals that, within the midstream sector, Guodian Nanrui achieves the highest average innovation efficiency at 44.00%, whereas Goldwind exhibits the lowest average efficiency at 15.12%, suggesting a notable disparity in innovation efficiency among midstream enterprises. Figure 3 shows that, for downstream enterprises, BYD commands the highest average innovation efficiency at 161.3%, whereas Maoshuo has the lowest average efficiency at 2.43%, indicating a larger difference in innovation efficiency among downstream enterprises compared to the upstream and midstream sectors. The data illustrate that, regardless of their position in the industry chain, some enterprises display higher innovation efficiency, while others face stagnation due to varying innovation foundations and demands.

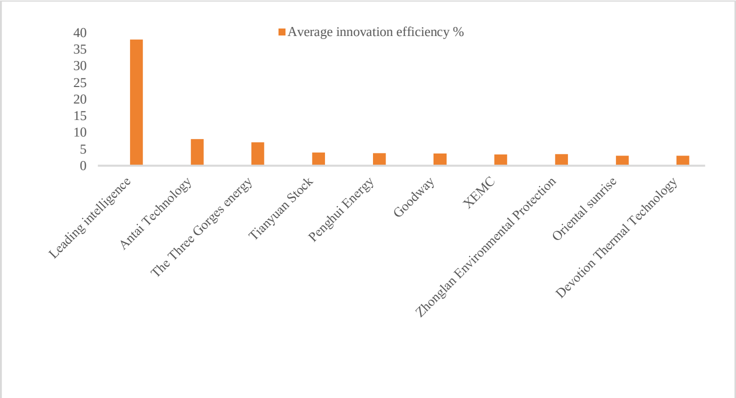

Figure 1. Top 10 upstream enterprises with average innovation efficiency

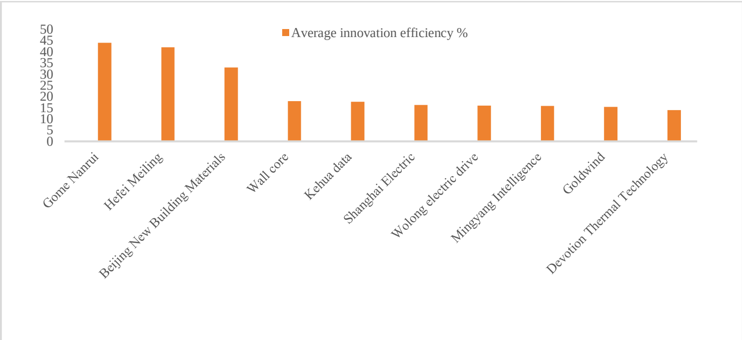

Figure 2. Top 10 Midstream enterprises in average innovation efficiency

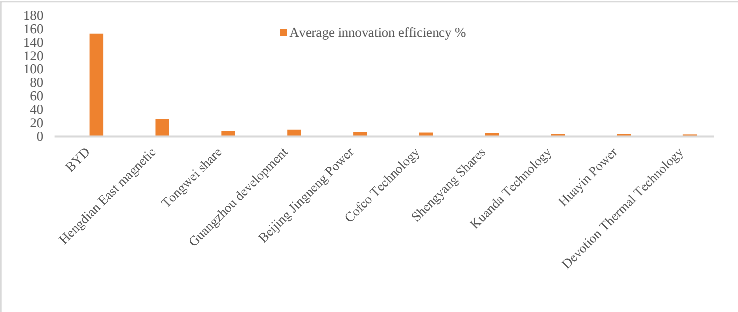

Figure 3. Top 10 downstream enterprises with average innovation efficiency

In conclusion, the results validate Hypothesis 2, highlighting the heterogeneity in innovation efficiency across different tiers of the new energy industry.

5 Conclusions and Suggestions

5.1 Research conclusions

Based on the public data of Shanghai and Shenzhen A-share new energy listed companies from 2019 to 2023, this paper examines the incentive effect of tax incentives and government subsidies on technological innovation of upper, middle and downstream enterprises through empirical analysis according to different positions of enterprises in the industrial chain. The results are as follows:

(1) Tax incentives and government subsidies can encourage enterprises to increase innovation investment and promote technological innovation.

(2) Tax incentives and government subsidies have different incentive effects on enterprise innovation input, innovation output and innovation efficiency. Some enterprises lack innovation willingness and innovation ability, and tax incentives and government subsidies have little incentive effect on technological innovation of these enterprises.

5.2 Policy suggestions

Fostering innovation-oriented mindsets among enterprises is key. The development of a comprehensive innovation ecosystem and the adoption of a holistic approach to evaluating technological innovation in high-tech sectors are imperative. This encourages firms to innovate proactively. To safeguard the integrity of the industrial and supply chains, policy tools such as tax breaks and subsidies should be strategically employed at various stages of industry development. This ensures that government financial resources are utilized effectively, while also promoting the scaling up and qualitative growth of the new energy industry.

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