Analysis on the Policy Mechanism and Optimization of Green Technology Innovation in Manufacturing Industry——Based on the Data of Listed Companies in the New Energy Vehicle Industry

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Abstract. Government policy is an important means to promote green technology innovation in enterprises. However, scholars are unsure whether government policy can achieve the expected results. This paper selects new energy automobile companies as the research object, collects relevant data of 28 listed companies in this field for nearly 10 years, and uses panel threshold models to empirically test the impact of environmental regulations and government subsidies on corporate green technology innovation. Research shows that environmental regulation can significantly promote green technology innovation. When the intensity of environmental regulations is appropriate, government subsidies can achieve the best drive for green technology innovation. This article reveals the influencing factors and mechanism of corporate green technology innovation from a micro perspective, providing a scientific basis for optimizing government policies and promoting the green development of Chinese manufacturing.

1. Introduction
In the context of the transformation and upgrading of China's manufacturing industry, the focus on increasing manufacturing production capacity and enhancing competitiveness is green technology innovation, which is also the key to national development. China has introduced a series of policies to promote green technology innovation in enterprises. In terms of the specific implementation methods of policies, they are mainly divided into fiscal policies and non-fiscal policies. Among them, fiscal policies are in the form of subsidies, tax incentives, and credit support. Non-financial policies are in the form of environmental regulations, personnel training services, and technical standards. According to the current policy implementation, environmental regulation and financial subsidies are the two main ways to promote green technology innovation in enterprises. However, the implementation effects are not satisfactory. There are problems such as the policy-driven effect is greater than the technological progress effect and regional development imbalance. Therefore, this paper focuses on the role of environmental regulations and financial subsidies on the green technology innovation of enterprises.

Scholars at home and abroad have carried out research on the relationship between environmental regulation and technological innovation. For example, Chakraborty et al. found that environmental regulation significantly promotes innovation input and output, and promotes its green transformation [1]. Guo et al. found that the impact of environmental regulations on corporate green innovation is characterized by first suppression and then promotion [2]. There is also a large amount of literature...
research on the impact of government innovation support on corporate technology innovation. For example, Chen Ling and Yang Wenhui's research used propensity score matching methods to overcome endogenousness, analyzed the role of government research and development subsidies on corporate innovation, and found that government subsidies have a positive incentive effect on corporate research and development [3]. Kou Mingting et al. conducted empirical research using Beijing's listed high-tech enterprises as research objects, and the research showed that government subsidies will have a crowding-out effect on corporate innovation [4]. Catozzella and Vivarelli found that there is a negative correlation between financial subsidies and R & D investment of enterprises without considering the heterogeneity of enterprises [5]. The shortcomings of the existing research results are mainly: 1. No consensus has been reached on the impact of various policies on corporate green technology innovation. 2. There is less literature on both fiscal and non-fiscal policies. 3. At present, the research on the influencing factors of green technology innovation in industries and regions has been relatively comprehensive, but the research from the micro level of enterprises is less. In addition, the new energy automobile industry has the industry specificity of facing "dual risks" of technology and market. The research conclusions based on high-tech enterprises are not necessarily applicable to the new energy automobile industry.

To sum up, this article selects listed companies of new energy vehicles as research objects, and in-depth studies on the impact of government financial subsidies and environmental regulations on new technology innovation of new energy vehicle companies and their mechanisms, which makes up for the regret of the existing insufficient research on new energy vehicles, with a view to providing reference for the government to formulate regional green technology innovation policies.

2. Research design

2.1. Sample selection and data sources
This research takes the emerging new energy vehicle industry as the research object. Among the Chinese A-share listed companies, 28 new energy vehicle listed companies whose main business is vehicle production and sales and whose new energy vehicle business accounts for a large proportion are selected. The data from 2010 to 2018 was used to construct a measurement model to analyze the influencing factors of green technology innovation in the new energy automobile industry. Green innovation-related data is obtained from the State Intellectual Property Office's website. Environmental regulation data comes from the China City Statistical Yearbook, and other variable data comes from the Guotai'yan database and the company's annual report on the Juchao website.

2.2. Variable measurement
Explained variable: green technology innovation. Existing studies have mostly used the unit energy consumption of new product production [6] or adopted the SBM model [7] to measure green innovation in stages. In order to overcome the limitations of existing research, and consider that patent grants are susceptible to factors other than technology, and have a certain lag, this article uses green patent applications to measure green innovation. Patent data was obtained through a combined search of the IPC classification number of the patentee and the green patent on the Internet of the State Intellectual Property Office. The IPC classification of green patents comes from Aghion's research on green innovation in the automotive industry [8], which is positively related to the level of green technology innovation development of enterprises.

Explanatory variables: subsidy intensity and environmental regulations. In recent years, the government's fiscal and tax policies for the new energy vehicle industry have focused on fiscal subsidies and tax incentives. This article chooses the ratio of "government subsidies" to operating income in the financial report as an indicator of the strength of subsidies. Existing literature has a variety of methods for measuring environmental regulations. This paper learns on the research of Change Kuang et al. [9], and measures the intensity of environmental regulations based on the green coverage of built-up areas in urban areas. From the micro level of the enterprise, this indicator is not only easy to obtain, it is closely related to the degree of environmental governance, and it is basically not affected by green
technology innovation, which avoids the endogenous problems that other measurement methods may bring.

Control variables: This paper includes governance characteristic variables and company characteristic variables into the control variable group. Among them, the characteristics of governance include: the proportion of independent directors, the concentration of equity, and salary incentives. The company's characteristic variables include: enterprise size, debt service ability, development ability, profitability, operating ability, and technical level. The specific variables are explained in Table 1.

Table 1. Variable definition and measurement.

| Type                  | Variable name         | Symbol   | Calculation                                                                                     |
|-----------------------|-----------------------|----------|-------------------------------------------------------------------------------------------------|
| Explained variable    | Green technology innovation | G-patents | Natural logarithm of the sum of green patent applications and 1                                |
| Explanatory variables | Subsidy intensity     | Cov      | Total government subsidy / Operating income                                                      |
|                       | Environmental regulation | ER       | Green coverage rate of built-up areas in urban areas                                            |
|                       | Proportion of independent directors | Indrc    | Independent directors / total directors                                                          |
|                       | Salary incentives      | Salary   | Top three executives' total salary / Operating income                                             |
|                       | Equity concentration   | Con      | Largest shareholder's shareholding / Total number of shares of the company                      |
|                       | Debt service ability   | Debt     | Net cash flow / Current liabilities from operating activities                                   |
|                       | Technical level        | Tech     | Net intangible assets / Total assets                                                            |
|                       | Operating ability      | Ope      | Accounts receivable / Operating income                                                           |
|                       | Profitability          | Profit   | (Total profit + Financial expenses) / Total assets                                               |
|                       | Development ability    | Dev      | (Total value of the period of assets-Initial value of the total period of assets) / Total value of the current period of assets               |
|                       | Enterprise size        | Size     | Natural logarithm of total assets                                                               |

2.3. Model settings
This article designs models (1) and (2) to test the impact of environmental regulations and the strength of government subsidies on green technology innovation, where i and t represent the company and year, Controlit stands for control variable group. uit, vit, and eit represent the fixed effect of the enterprise, the fixed effect of time, and the random disturbance term, respectively. Referring to Wang Xu's research method [10], a triple panel threshold model is used to test the threshold effect of subsidy intensity on green technology innovation, as shown in equation (3). I(·) is the instruction function. It takes 1 when the conditions in the brackets are met, otherwise it takes 0. Covit is the threshold variable, and y1 is the threshold threshold.

\[ G - \text{patents}_{it} = \alpha + \beta_1 \text{Cov}_{it} + \sum \theta_i \text{Control}_{it} + u_i + v_t + e_{it} \]

(1)

\[ G - \text{patents}_{it} = \alpha + \beta_1 ER_{it} + \sum \theta_i \text{Control}_{it} + u_i + v_t + e_{it} \]

(2)

\[ G - \text{patents}_{it} = \alpha + \beta_1 \text{Cov}_{it} I(ER_{it} \leq y_1) + \beta_2 \text{Cov}_{it} I(y_1 < ER_{it} \leq y_2) + \beta_3 \text{Cov}_{it} I(y_2 < ER_{it} \leq y_3) + \beta_4 \text{Cov}_{it} I(ER_{it} > y_3) + \sum \theta_i \text{Control}_{it} + u_i + v_t + e_{it} \]

(3)

3. Analysis of empirical results

3.1. Descriptive statistics
According to the range, average level and fluctuation of the variables, the statistical description of the relevant variables is shown in Table 2. The results show that: 1. Green technology innovation indicators. The minimum value of green technology innovation of each enterprise is 0, the maximum value is 6.561,
and the standard deviation is 2.015, indicating that the enterprise's green innovation is unbalanced. 2. The standard deviation of the subsidy intensity is 0.012, which indicates that the difference in the intensity of government subsidies received by the sample companies is relatively small, reflecting the government's greater policy support for new energy automobile companies, and the policy access rules are relatively loose. The standard deviation of environmental regulations is 4.888, which indicates that the pressure on environmental regulations varies greatly among enterprises. 3. Among the other variables, only the standard deviation of equity concentration and enterprise size is large, while the standard deviation of other variables is small, indicating that the overall fluctuation of the control variable is small.

| Variable | Min | Max | Mean | Std | N  |
|----------|-----|-----|------|-----|----|
| G-patents | 0.000 | 6.561 | 2.755 | 2.015 | 252 |
| ER       | 25.050 | 61.580 | 40.677 | 4.888 | 252 |
| Cov      | 0.000 | 0.137 | 0.008 | 0.012 | 252 |
| Indrct   | 0.300 | 0.571 | 0.364 | 0.051 | 252 |
| Salary   | 0.000 | 0.037 | 0.000 | 0.003 | 252 |
| Con      | 7.180 | 74.300 | 36.484 | 16.670 | 252 |
| Debt     | -1.160 | 1.280 | 0.110 | 0.211 | 252 |
| Tech     | 0.000 | 0.159 | 0.047 | 0.116 | 252 |
| Ope      | 0.002 | 1.173 | 0.190 | 0.157 | 252 |
| Profit   | -1.602 | 0.187 | 0.474 | 0.116 | 252 |
| Dev      | -0.668 | 1.920 | 0.174 | 0.259 | 252 |
| Size     | 20.155 | 27.386 | 23.206 | 1.449 | 252 |

Table 2. Descriptive statistics of the main variables.

3.2. Fixed effect model

Table 3. Fixed effect model.

| Explanatory variables | Model 1 | Model 2 | Model 3 |
|-----------------------|---------|---------|---------|
|                       | coefficient | t-value | coefficient | t-value | coefficient | t-value |
| ER                    | 0.0503***  | 2.65     | 9.5856     | 1.39    | 0.3083***  | 3.25    |
| Cov                   |           |          |           |         |            |         |
| Cov*Cov               |           |          |           |         |            |         |
| Indrct                | -1.0045   | -0.74    | -1.5532    | -1.11   | -2.2980    | -1.65   |
| Salary                | -0.1747** | -2.38    | -0.2694**  | -2.55   | -0.5297*** | -3.96   |
| Con                   | 0.0237    | 1.64     | 0.0214     | 1.47    | 0.0261*    | 1.81    |
| Debt                  | -0.5881*  | -1.80    | -0.5903*   | -1.79   | -0.5444*   | -1.68   |
| Tech                  | 0.2292*** | 2.74     | 0.2244**   | 2.57    | 0.2520***  | 3.03    |
| Pro                   | 0.3771    | 0.68     | 0.4798     | 0.86    | 0.3014     | 0.55    |
| Profit                | 0.1538    | 0.29     | 0.0590     | 0.11    | -0.4122    | -0.76   |
| Dev                   | 0.1450    | 0.77     | 0.2231     | 1.16    | 0.2196     | 1.17    |
| Size                  | 0.9461*** | 6.78     | 0.9607***  | 6.80    | 1.0235***  | 7.40    |
| R-sq                  | 0.3529    | 0.3376   | 0.3630     |         |           |         |
| F                     | 27.07***  | 27.85*** | 29.28***   |         |           |         |

This article separately verified the impact of government innovation subsidies or environmental regulations on corporate green innovation. The results are shown in Table 3. According to Model 1, the regression coefficient of the environmental regulation variable is 0.0503, and it passed the significance test at the level of 0.01, indicating that environmental regulation has a significant promotion effect on the green technological innovation of enterprises. This regression result shows that environmental regulation is conducive to green technology innovation of enterprises, that is, when companies face additional costs imposed by environmental regulation, they will be inclined to favor green technology innovation. From Model 2, it can be seen that there is no significant linear correlation between government subsidy intensity variables and green technological innovation. Referring to the general
practice, the square term of the intensity of government subsidies is introduced in model 3, and it is found that it has a positive correlation with the green technological innovation capability of the enterprise (0.3083, p < 0.01), and it is a nonlinear correlation form. That is, when the subsidy intensity is less than a certain threshold, as the subsidy intensity increases, it has a suppressive effect on green technological innovation. When the subsidy intensity is greater than a certain threshold, as the subsidy intensity increases, it promotes green technological innovation.

3.3. Threshold effect of environmental regulation
This article uses the "self-sampling method" to test the significance of the threshold number. The results are shown in Table 4. The threshold effect of environmental regulation in the relationship between subsidy intensity and green technological innovation passed the single threshold test at the level of 0.05, and the double and triple threshold effect was not significant. Table 5 reports the results of environmental regulatory threshold thresholds and confidence intervals. In the relationship between subsidy intensity and green technological innovation, the threshold of environmental regulation is 43.10, and the confidence interval is [42.9850, 43.1300].

| Threshold variable | Threshold estimate | 95% confidence interval |
|--------------------|--------------------|-------------------------|
| ER Th-1            | 43.10              | [42.9850, 43.1300]      |

Table 4. Threshold existence test.

| Threshold | Fstat | Prob | Bootstrap |
|-----------|-------|------|-----------|
| Single    | 18.49 | 0.0100 | 300       |
| Double    | 3.42  | 0.8033 | 300       |
| Triple    | 8.78  | 0.2100 | 300       |

Table 5. Threshold existence test.

Table 6. Threshold panel model estimation results.

| Explanaind variables | coefficient | t-value | p-value |
|----------------------|-------------|---------|---------|
| Cov1                 | -3.3793     | -0.46   | 0.648   |
| Cov2                 | 36.6967***  | 3.88    | 0.000   |
| Indrect              | -1.7216     | -1.27   | 0.206   |
| Salary               | -0.6006***  | -4.58   | 0.000   |
| Con                  | 0.02624*    | 1.85    | 0.065   |
| Debt                 | -0.7428**   | -2.31   | 0.022   |
| Tech                 | 0.2417***   | 2.93    | 0.004   |
| Ope                  | 0.1386      | 0.25    | 0.726   |
| Profit               | 0.8317      | 1.49    | 0.137   |
| Dev                  | 0.0797      | 0.42    | 0.673   |
| Size                 | 1.0129***   | 7.38    | 0.000   |
| R-sq                 | 0.3844      |         |         |
| F                    | 28.88***    |         |         |

Table 6 reports the results of testing the threshold effect of the relationship between subsidy intensity and green technological innovation. When ER < 43.10, the regression coefficient of subsidy intensity is negative, but not significant; when ER > 43.10, the regression coefficient of subsidy intensity is 36.6967, and the significance level is 0.01. When environmental regulations are greater than this threshold, the intensity of subsidies can significantly improve the efficiency of green technology innovation of enterprises, but below this threshold, because the cost imposed on enterprises by environmental regulations is less than the cost of R & D, companies choose to adopt old technologies production without engaging in green R & D makes government subsidies unable to promote green innovation for enterprises.
4. Conclusions
The specific conclusions and related countermeasures of this article are as follows:

1. At the current stage, the intensity of environmental regulations can be appropriately increased. The research in this paper finds that there is a positive linear relationship between environmental regulation and green technology innovation, and that environmental regulation presents a negative to positive, and from insignificant to significant threshold effect on the relationship between government subsidies and green technology innovation; statistical data also found that at present, the intensity of environmental regulation in most areas has not crossed the threshold or has just crossed the threshold, and the intensity of environmental regulation is generally low. Therefore, it is necessary to gradually increase the intensity of environmental regulations in order to internalize the external costs of enterprises and promote green technological innovation.

2. Control the intensity of financial subsidies in a "moderate range" in accordance with the environmental regulatory intensity of each region. Through panel threshold regression analysis, it is found that there is a "U" relationship between government subsidies and green technology innovation. In the case of relatively weak environmental regulations, government subsidies have not significantly promoted the green technological innovation of enterprises. This shows that weak environmental regulations cannot stimulate the innovation momentum of enterprises. Therefore, the government should give full consideration to the differences in various regions, and use two methods of environmental regulation and financial subsidies to formulate policies in order to give full play to the incentive effect of financial subsidies and further promote the research and innovation of new energy vehicle manufacturers.

3. Both sides of the government and enterprises work together to achieve win-win cooperation. Research shows that enterprise scale and technology level have a significant role in promoting green technology innovation. Therefore, from the perspective of the government, it should try to implement different subsidy strengths and programs for different enterprises, establish a perfect subsidy post-mortem monitoring and audit mechanism, and ensure that subsidy funds are strictly used for the development of green technologies. From the perspective of a new energy vehicle manufacturer, it is necessary to continuously improve the company's strategic decision-making governance, increase research and development investment, and establish a strategic decision-making mechanism conducive to research and innovation.

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