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The Influence and Mechanism Analysis of Environmental Regulation on Green Technology Innovation of Enterprises

Gen Zuo

School of Hunan University of Science and Technology, Xiangtan 411100, China

Abstract: By collecting the micro data of China's A-share listed enterprises, this paper studies the impact of environmental regulation on the green technology innovation of heterogeneous enterprises based on the perspective of "Porter hypothesis". It is found that environmental regulation can effectively promote the green technology innovation level of enterprises. And the conclusion remains robust after controlling for endogeneity, replacing the explained variables, and changing the time series. In the heterogeneity analysis, due to the differences in enterprise strength and social responsibility between state-owned enterprises and non-state-owned enterprises, environmental regulation has different effects on the green technology innovation effect of enterprises with different features. Due to the good economic foundation and resource endowment in the eastern region and the western region, the environmental regulation has a more obvious effect on the green technology innovation of enterprises in this region. The central region does not have these advantages, the effect is not significant. In the mechanism analysis, the cost mechanism and the compensation of innovation mechanism proposed by the theoretical analysis are verified.

Keywords: Environmental regulation, Green technology innovation.

1. Introduction

In recent years, China has been increasing its efforts in environmental protection, and various government documents are also emphasizing environmental protection. From the Sixth Five-Year Plan for National Economic and Social Development of the People's Republic of China emphasizing environmental protection for the first time, to the 12th Five-Year Plan, the 13th Five-Year Plan and the 14th Five-Year Plan promulgated in recent years, the importance of environmental protection was emphasized. In 20th annual report, Xi stressed that "we must firmly establish and practice the concept that clear waters and lush mountains are mountains of gold and silver, and plan development from the height of harmonious coexistence between man and nature."Further through the method of text analysis, with the help of jieba sub-database in python, calculate the "12th Five-Year Plan", "13th Five-Year Plan" and "14th Five-Year Plan", and study the key points and change trends emphasized in government document. The results show that from the 12th Five-Year Plan period to the 13th Five-Year Plan period, the country has further strengthened environmental protection, especially in the "green" and "innovation", the number of emphasis has been greatly improved. From the "13th Five-Year Plan" period to the "14th Five-Year Plan" period, the country's emphasis on environmental protection is almost unchanged, and the emphasis on "green" and "innovation" is basically the same as the previous period. Both from the perspective of qualitative research and quantitative analysis, it highlights the continuous strengthening of environmental protection in China in recent years.

2. Literature Review

Regulation’s appearance first was in Hicks' wage theory[1]. He believed that because there was deception, and deception was difficult to be accurately detected. So economic regulation was difficult to achieve good results. By 1995, Poter had introduced the famous Porter hypothesis, arguing that stricter environmental regulations would spur corporate innovation[2]. There has been a fierce debate around the "Porter hypothesis", and scholars are been it from different perspectives.

Based on the perspective of heterogeneous environmental regulation, different scholars analyze the impact of environmental regulation on the green technology innovation of enterprises from the perspectives of voluntary participation environmental regulation, informal environmental regulation and market incentive environmental regulation. Based on the micro data of agriculture-related listed enterprises from 2010 to 2019, Y. Chu et al[3] analyzed the characteristics of green technology innovation behavior of agricultural-related enterprises under the voluntary environmental regulation. The result showed that voluntary environmental regulation had the characteristics of green technology innovation of agriculture-related enterprises.From the perspective of informal environmental regulation, it is divided into "public concern" and "media concern". J.H. Sun et al[4] found that the public attention could significantly promote the green technology innovation of enterprises, and the media attention had an "inverted U-shaped" relationship between the green technology innovation of enterprises.With the help of different market incentive environmental regulation policies, B. Shang et al[5] used the way of game theory to analyze the process of enterprises choosing the green technology innovation mode. Research found that the use of innovative process cost subsidy was more conducive to enterprises to carry out green technology innovation.

Based on the perspective of green technology innovation, J.R. Wang and Y. Zhang[6] believed that the willingness of green technology innovation had a significant role in promoting the green technology innovation behavior. With the use of fuzzy set qualitative comparative analysis (fsQCA) method, X. Gao et al[7] found that environmental regulation could realize the "innovation compensation effect" of green

technology innovation only by cooperating with high R&D investment and high market demand. Y.Q. Liu et al[8] believed that environmental policy had a U-shaped relationship between green technology innovation in the region. Not only did environmental policies have an impact on green technology innovation, but digital economy, finance and other factors also had a significant impact on green technology innovation. Based on the panel data of 30 provinces and cities in China from 2013 to 2020, Y.J. Wang and Q.J. Gao[9] found that the influence of digital economy industry, digital economy manufacturing industry and digital economy service industry agglomeration on green technology innovation was "inverted U-shaped". X.M. Chen et al[10] thought, Digital finance played a positive role in promoting the green technology innovation of enterprises. T.Y. Zhong et al[11] used the data of a-share listed enterprises from 2011 to 2019 to study the impact of digital inclusive finance on the green technology innovation of enterprises. The research results showed that the digital inclusive finance played a significant role in promoting the green technology innovation of enterprises. By further dividing the categories of green technology innovation, it was found that the effect of digital financial inclusion was significantly different between substantive green technology innovation and strategic green technology innovation.

3. Theoretical Analysis and Research Hypothesis

3.1. Based on Short-term Costs

Poter believes that moderate environmental regulation will stimulate technological innovation in enterprises[2]. The emphasis on moderation is that excessive environmental regulation will cause the increase of production costs of enterprises, compress the profits of enterprises and then affect the R&D investment of enterprises, and ultimately reduce the technological innovation level of enterprises[12]. In the short term, the environmental protection policy formulated by the government will force enterprises to carry out the production process transformation, thus increasing the production cost of enterprises, thus facing the trend of declining profits, and ultimately inhibiting the green technology innovation of enterprises.

Based on the above analysis, Hypothesis 1 is proposed: in the short term, environmental regulation will bring the pressure of rising costs and restrain the green technology innovation of enterprises.

3.2. Based on Long-term Innovation Compensation

In the long run, the market is clear, and those enterprises with insufficient level of technological innovation will be due to low level of competitiveness, and eventually eliminated. Due to the reduction of competitors and the improvement of productivity level, the remaining enterprises can occupy more market share and reduce the production cost of the unit product, and eventually obtain higher profits.

Based on the above analysis, Hypothesis 2: in the long term, due to the clear market, enterprises with high green technology innovation level can significantly improve their profits, which encourages enterprises to increase R&D investment at present and improve the level of green technology innovation.

4. Research Design

4.1. Sample Selection and Data Source

This paper selects the A-share listed enterprises from 2008 to 2020 as samples. Due to the data loss and data availability, the panel data of 574 enterprises are finally formed. The sample was taken in 2008 because China has achieved remarkable results in pollution control during the 11th Five-Year Plan period, and the total industrial sulfur dioxide emission has decreased significantly. However, considering the time lag of the policy, the middle period of the 11th Five-Year Plan was selected as the starting year of the sample.

The green patent data of this paper comes from the State Intellectual Property Office and the World Intellectual Property Office (WIPO). First, the patent data of the sample are retrieved by the State Intellectual Property Office, including the IPC number of each patent.Then those data are matched with the green IPC published by the World Intellectual Property Office. Further, considering that some enterprises have changed the used names, which will lead to the statistics of the enterprise patent number are less than the actual. In order to avoid this statistical bias, we manually check the names of all enterprises firstly, then collect patent information of enterprises with the help of the State Intellectual Property Office. Other variables in this paper are from CSMAR database and China Statistical Yearbook. In order to avoid possible bias caused by extreme values, two-sided 1% tailed on the main data.

4.2. Variable Setting

4.2.1. Environmental Regulation

There are many kinds of academic measures of environmental regulation indicators. Eli Berman and L.T.M.Bui[13]Adopt the most direct method to directly count the number of environmental protection documents issued by the government, and take this as the measurement index of environmental regulation. D.H. Yu et al[14] take operating cost of pollution treatment facilities as the proxy variable of environmental regulation. However, the above measurement indicators have weak data quality, which cannot accurately reflect the intensity of environmental regulation. Therefore, this paper adopts Gray's method, and adopts the share of the average amount of pollution control of listed companies in the total cost of enterprises as the measurement index of environmental regulation[15]。

4.2.2. Green Technology Innovation

This paper searches the patent information of each enterprise through the State Intellectual Property Office, combines the "green" IPC classification list published by the World Intellectual Property Office, sorts out the green patent data of enterprises, and takes this as an indicator to measure the green technology innovation level of enterprises. In the robustness test, green invention patent (invgreen),whose innovation is more stronger, is used as the index to measure the green technology innovation level of enterprises

4.2.3. Control Variables

Referring to S.Z. Qi et al[16] and J.K. Liu et al[17], the control variables include enterprise age (age), asset-liability ratio (lev), logarithm of total revenue (ln totalinc), logarithm of total assets (ln totalcapi), logarithm of enterprise employees (ln staffnumb), and logarithm of Tobin Q (ln tobinq).See Table 1 for the above variables indicators.

Table 1. Variable names and measurement methods

Class	Variable symbol	Measurement method
Explained variable	green	Number of enterprise green patents
Explanatory variable	ers	The average amount of pollution control of listed companies accounts for the total cost of enterprises
Controlled variables	age	The year of enterprises establish
	lev	Asset-liability ratio of enterprises
	ln totalinc	The log value of the total enterprise revenue
	ln totalcapi	The log value of the enterprise's total assets
	ln staffnumb	The log value of the enterprise employees
	ln tobinq	The log value of the enterprise tobinQ

4.3. Model Setting

$$green_{it} = c + \beta_1 ers_{it} + \theta X_{it} + \sum year + \varepsilon_{it} \quad (1)$$

$$\ln netprof_{it} = c + \beta_1 ers_{it} + \theta X_{it} + \sum year + \varepsilon_{it} \quad (2)$$

Model (1) studies the impact of environmental regulation on the technological innovation of enterprises. X represents the control variables in the model, and ε_{it} represents the random disturbance items. Model (2) is used to verify the hypothesis 1 and hypothesis 2 in the theoretical analysis. The ln netprof is the logarithm of the enterprise's net profit.

5. Analysis of the Empirical Test Results

5.1. Benchmark Regression Test

Table 2 columns (1) and (2) both adopt fixed effect models. Column (1) controls the time effect while controlling the individual effect, and column (2) does not control the time effect of the enterprise. Different random effects models are used in columns (3) and (4). The above results at the 1% significance level indicate that environmental regulation promotes the green technology innovation of enterprises. Further, the fixed-effect model and the random-effects model showed that the p-value was 0.0142, so it was more reasonable to reject the hypothesis that non-observed effects were unrelated to the explanatory variables at the 5% significance level, and to choose the fixed-effect model.

Table 2. Benchmark regression results

	(1)	(2)	(3)	(4)
Variable	FE	FE	RE_FGLS	RE_MLE
ers	21.442***	21.561***	16.472***	16.587***
	(2.70)	(2.72)	(2.91)	(3.04)
Constant	-86.376***	-29.401***	-31.267***	-31.151***
	(-8.32)	(-3.11)	(-3.72)	(-8.94)
Observations	5,366	5,366	5,366	5,366
R-squared	0.064	0.063		
Individual effect	Yes	Yes	Yes	Yes
Time effect	Yes	No	Yes	Yes
Controlled variables	Yes	Yes	Yes	Yes

Note: *, * * and * * * are significant statistics at significance levels of 10%, 5% and 1% respectively; t statistics in parentheses; the estimated standard error is clustered to the enterprise level, the same below

5.2. Heterogeneity Analysis

5.2.1. Heterogeneity of Enterprises' Feature

There are differences between state-owned enterprises and non-state-owned enterprises in corporate goals, corporate vision and social responsibility[18]. In the face of government environmental policies, State-owned enterprises and Non-state-owned enterprises may make different market responses. Table 3, column (1) (2), shows the impact of environmental regulation on the green technology innovation of state-owned enterprises and non-state-owned enterprises. The results show that environmental regulation can promote the green technology innovation of state-owned enterprises at the significance level of 5%, but it does not promote the green technology innovation of non-state-owned enterprises. With their strong financial strength and social responsibility, state-owned enterprises are often more motivated to carry out green technology innovation. In contrast, non-state-owned enterprises often lack enough funds for research and development, so it is difficult to effectively make green technology innovation in the face of the government's environmental policies.

5.2.2. Regional Heterogeneity

Enterprises in different geographical locations may be affected by the local environment, economy, culture, customs, etc. When faced with environmental regulations formulated by the government, enterprises in different geographical locations will take different measures to deal with them. In This paper, the sample enterprises are divided into three parts: eastern, central and western parts, which correspond to column (4) (5) (6) of Table 3 respectively. As can be seen from Table 3, the environmental regulation of enterprises in eastern and western regions can promote green technology innovation of enterprises at the significant level of 10%, and have a greater impact on green technology innovation of enterprises in western regions than that in eastern regions. The central region was not significant. Due to the developed

economy, the eastern region has gathered some heavy polluting enterprises. When the country implements environmental regulations, under pressure, enterprises will invest more funds in research and development, which indirectly improves the level of green technology innovation. Due to the slow economic development in the central region, enterprises are more cautious in innovation investment and pay insufficient attention to green technology innovation[18]. The western region is rich in mineral resources and developed mining industry, and mining industry as a heavy pollution industry, which brings serious environmental problems. When faced with environmental regulations, these heavy polluting enterprises must increase their investment in research and development, upgrade their technologies, and adopt more green technologies. This indirectly improves the level of green technology innovation of enterprises.

Table 3. Analysis of heterogeneity

	(1)	(2)	(4)	(5)	(6)
Variable	State-owned enterprises	Non-state-owned enterprises	East area	Middle area	West area
ers	25.696**	19.749	28.189*	10.251	35.926*
	(2.32)	(1.37)	(1.85)	(0.90)	(1.69)
Constant	-37.162*	-24.042***	-33.927**	-11.117	-13.098
	(-1.96)	(-2.72)	(-2.43)	(-0.89)	(-1.38)
Observations	3,131	2,237	3,438	1,105	825
R-squared	0.084	0.052	0.070	0.065	0.101
Individual effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes

5.3. Robustness Test

5.3.1. Endogenity Problem

Although the fixed-effect model can reduce the bias caused by missing variables to some extent, it is not effective for unobservable variables that change over time.We take the lag of environmental regulation variable as the instrumental variable. By using instrumental to avoid the endogenous problem. The regression results show that at the significance level of 1%, environmental regulation can effectively promote the green technology innovation of enterprises, and the results are still established. And the Kleibergen-Paap rk Wald F statistic is 29.203, which is greater than the critical value of 16.39 indicated by Stock and Yogo (2002). Suggesting that the regression results are robust.

5.3.2. Replace the Explained Variable

This paper takes the number of enterprise green patents as the index to measure the green technology innovation of enterprises, while the invention patents are more innovative. Therefore, the number of enterprise green invention patents is taken as a measurement index to test the reliability of the experimental conclusions. The results show that with a 10% significance level, environmental regulation can promote green technology innovation in enterprises. It shows that the conclusion remains after replacing the explained variables.

5.3.3. Change the Time Series

As the results of green technology innovation in enterprises need time, this paper examines the impact of environmental regulation in this period on the next phase of green technology innovation. The regression results show that the coefficient of environmental regulation is 19.509, and the p-value is 0.019. At the significance level of 5%, it shows that environmental regulation has a promoting effect on the green technology innovation of enterprises, and the results are still valid.

6. Further Analysis

6.1. The Cost Mechanism

The theoretical analysis part points out that, in the short term, enterprises have to carry out green technology innovation due to the downward pressure on profits caused by rising costs. In order to reflect the characteristics of short-term, take into account that the "five-year plan" is five years. Therefore, the age of the enterprise is not higher than five years as the constraint of regression. As in Table 4, in the short term, environmental regulation will reduce corporate profits and inhibit green technology innovation of enterprises, thus verifying the hypothesis 1.

6.2. Compensation of Innovate

In the long run, the market is clear. Companies with low productivity levels will be eliminated, and only those with high productivity levels can remain in the market. If enterprises want to survive the fierce competition, they must increase investment in research and development and improve their productivity. The remaining enterprises can not only obtain a higher market share, but also greatly improve the output per unit input and improve the production efficiency to reduce the cost of unit product. In order to obtain these benefits in the future, enterprises will increase their R&D investment in the current period to promote their green technology innovation. Because in the long run, the market is clear, and only a few enterprises remain in the market. The older the enterprise is, the more it can indicate that the enterprise can survive in the competition. Therefore, the 90% quantile of the enterprise age was used as a constraint for the regression. As can be seen in Table 2(2), environmental regulation can promote green technology innovation of enterprises at the 1% significance level, which verifies the hypothesis 2.

Table 4. Mechanism test

	(1)	(2)
	Cost mechanism	Compensation of Innovate
Variable	ln netprof	ln netprof
ers	-12.346**	26.828***
	(-2.12)	(6.18)
Constant	-25.285***	-11.571***
	(-4.06)	(-5.03)
Observations	87	610
R-squared	0.750	0.415
Controlled variable	Yes	Yes
Individual effect	Yes	Yes
Time effect	Yes	Yes

7. Conclusion

This paper is based on the micro data of a-share listed enterprises from 2008 to 2020, and manually arranges the green patent data of enterprises to study the impact of environmental regulation on the green technology innovation of enterprises. The results show that environmental regulation can effectively promote enterprises to carry out green technology innovation, and the conclusion is still valid after the robustness tests such as controlling the endogeneity, replacing the explained variables and changing the time series. In the heterogeneity analysis, there are obvious differences between state-owned enterprises and non-state-owned enterprises. For state-owned enterprises, due to their strong financial strength and stronger sense of social responsibility, they are often more motivated to carry out green technology innovation when they are faced with environmental policies formulated by the government. Non-state-owned enterprises, in lack of sufficient funds, often fail to increase R&D investment in a timely manner, so they are not willing to carry out green technology innovation. Regional differences can also have implications for the conclusions. Due to the developed economy in the eastern region, the agglomeration phenomenon is more obvious. When faced with environmental regulations, enterprises have enough strength to increase R&D investment. Because of the developed mining industry, the mining industry is a heavy polluting enterprise, which is also the most affected by environmental regulations. In order to make the production activities continue, enterprises can only use clean technology, constantly improve the production methods, and actively carry out green technology innovation activities. Due to its economic and geographical characteristics, the central region is least affected by environmental regulations, so enterprises are not strongly willing to carry out green technology innovation activities. Mechanistic test verifies two hypotheses proposed in the theoretical analysis. It respectively verifies the pressure forcing mechanism faced by enterprises in the short term and the innovation compensation mechanism pursued by enterprises in the long term.

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