Study on the Impact of Environmental Tax on Corporate Green Innovation under the Dual Carbon Target based on A-Share Mining Listed Companies

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Abstract. Will the collection of environmental protection tax promote the green innovation of enterprises? Under the call of the 20th National Congress of the Communist Party of China to increase pollution prevention and ecological protection, this paper is based on Porter's hypothesis, taking China's Shanghai and Shenzhen A -share industrial listed companies from 2010 to 2020 as the research object, and empirically tested the impact of environmental protection tax on corporate green innovation. The research finds that: environmental protection tax significantly promotes green innovation of enterprises, and presents a hysteresis feature, that is, the current environmental tax significantly improves the level of green innovation of enterprises in the next period and the next period. After analysis, it is found that the role of environmental tax in promoting green innovation of enterprises is mainly reflected in state-owned enterprises, large-scale enterprises, and enterprises with low financing constraints. The research conclusions theoretically enrich the literature on the research on the economic consequences of environmental taxes and the research on the influencing factors of corporate green innovation, and provide important inspiration for improving China's environmental tax system and improving corporate green innovation in practice.

Keywords: Double Carbon; Environmental Protection Tax; Mining Industry; Green Innovation; Porter Hypothesis.

1. Introduction

The report of the 20th National Congress of the Communist Party of China pointed out that in order to promote the construction of a beautiful China, it is necessary to systematically adjust the industrial structure, increase pollution prevention and control and ecological protection. Industrial emissions are the main cause of environmental problems. Enterprise green innovation is an effective way to improve and has attracted much attention from the academic circle.

On January 1 , 2018 , the "Environmental Protection Tax Law of the People's Republic of China" came into effect. According to the " Industry Classification Results of Listed Companies for the Third Quarter of 2021 " released by the China Securities Regulatory Commission , the categories of industrial companies include : mining, manufacturing, electricity, heat, gas, and water production and supply. Because each industry has certain differences in the scope of daily business activities, service objects, industry conditions, etc., therefore, the perception and response intensity of each industry to environmental protection tax will also be different. Among them, the mining industry is the most destructive to the environment. According to the "China Environmental Statistical Yearbook 2021 ", the discharge of waste gas from the mining industry is 1, 284, 640 tons, accounting for 11.99% of China's total discharge ; the discharge of industrial wastewater is 21, 900 tons, accounting for 4.8% of the total discharge of industrial wastewater; The amount of hazardous waste is 1.545 billion tons, accounting for 42.04% of China's total emissions ; the amount of hazardous waste generated is 8.3356 million tons, accounting for 11.45% of the total amount of hazardous waste generated .

The main contributions of this paper are reflected in the following aspects: First, unlike the previous preference of paying attention to the effect of environmental protection tax on macroeconomic development and environmental governance, this project focuses on examining the impact of listed companies on environmental regulation and corporate behavior from the micro level. Second, most scholars focus on the theoretical research of environmental protection tax and the " double dividend " effect, but this paper studies its impact on green innovation of enterprises from the perspective of environmental protection tax. Third, the existing research on the measurement of

corporate green innovation is mainly based on the questionnaire survey method. This paper uses green innovation to quantitatively measure corporate green innovation, which is more objective and convincing. Fourth, this paper takes the mining enterprises under the pressure of environmental protection tax as the object of research, dynamically analyzes the amount of pollutant discharge, patent applications, etc., explores the green innovation behavior of enterprises, and gives corresponding policy suggestions.

The remaining key contents of this paper are literature review, mechanism of environmental regulation, empirical analysis, conclusions and policy recommendations. The main research methods include literature induction method, text analysis method, comparative analysis method, model method and so on.

2. Literature Review

2.1 Research on the Impact of Environmental Regulation on Enterprise Green Innovation

There are three views on the impact of environmental regulation on corporate green innovation: one is " inhibition theory ". Tax pressure will reduce the funds available to enterprises and interfere with technological innovation of enterprises.［1］ The collection of environmental protection tax will increase the company's production cost, thereby reducing the company's competitive advantage and is not conducive to the company's technological innovation. The second is " facilitation theory " . The famous American professor Porter (1991) thinks that " inhibition theory " is relatively one-sided. In the long run, environmental protection tax is conducive to the green development of enterprises, and the pressure of increasing costs will push enterprises to improve their technological innovation level and reduce emissions, and the production efficiency and competitiveness of enterprises will also be strengthened. This view gradually evolved into the famous " Porter Hypothesis " . The third is " uncertainty theory " . The relationship between environmental regulation and enterprise technology innovation is "U" shape. Other studies have found that the intensity of environmental regulation and the degree to which enterprises adopt green technologies present an inverted "U" -shaped relationship.

2.2 Literature Review

The existing literature has achieved a lot of results, which is of great help to further refine the research direction and research objectives of this paper, but there are still the following deficiencies : (1) the existing research on the economic consequences of environmental protection taxes mainly focuses on macroeconomic development and There is a lack of micro-level research on the impact of pollution control effects. How the collection of environmental protection tax affects the green innovation behavior of enterprises needs further research. (2) Most scholars focus on the theoretical research of environmental protection tax, the " double dividend " effect or the impact of environmental regulation on corporate green technology innovation, and there are few studies on the direct use of environmental protection tax and corporate technological innovation.[2] (3) Existing studies on the influencing factors of corporate green innovation mainly include environmental regulations, government supervision, upstream and downstream factors, internal factors, etc., and less attention has been paid to the impact of environmental protection tax on corporate green innovation. As an economic incentive environmental regulatory tool, environmental protection tax is significantly different from other environmental regulatory tools. Whether it will force enterprises to innovate green and whether it has a driving or inhibiting effect on the green development of enterprises is worthy of further discussion. (4) There are limitations in the research method. On the one hand, previous studies on the measurement of corporate green innovation were mainly based on questionnaire survey methods, which lacked objectivity, and most of them were analytical methods of theoretical models, and convincing empirical research has not yet been obtained; on the other hand, there are few previous literatures Paying too much attention to the endogenous problems of environmental protection taxes will lead to insufficient identification of causal effects.

3. The Mechanism of Environmental Regulation

The specific manifestation of the mechanism of environmental protection tax affecting green innovation of enterprises is dual. First of all, environmental protection tax can promote green innovation. First, companies are forced to carry out green innovation. The "Environmental Protection Tax Law" introduces an information disclosure system, making public supervision possible and strengthening penalties. Second, accelerate the implementation of green innovation by enterprises. Environmental tax can guide enterprises to improve their processes, stimulate enthusiasm for green innovation, and reduce the risks they face in the innovation process. Third, increase the market share of the enterprise. Customers are willing to pay for high-priced green products, and companies that take the lead in green innovation can gain advantages in technology and products, and be the first to formulate industry or commodity standards. Fourth, the government encourages relevant support policies. If supported by government policies and funds, companies will be bolder in research and development. Second, environmental tax has an inhibitory effect on green innovation. [3] First, increase the additional burden on enterprises. Rising operating costs of enterprises may reduce the company's research and development expenses. Second, increase the business risk of the enterprise. Enterprises will avoid the implementation of green innovation due to the risk of improvement failure and external environment changes. Third, the inertial obstacles of the enterprise. The greater the difference between the new process and technology and the old one, the greater the resistance to innovation within the enterprise.

4. Research Design

4.1 Sample Selection and Data Sources

This paper selects the data of China's Shanghai and Shenzhen A -share listed companies from 2010 to 2020 as the initial research sample.

And the sample data is processed as follows: first, remove the more special data of financial listed companies in the sample; second, remove the samples that have delisting risks and contain missing values; third, shrink the continuous variables by 1 % Tail processing to prevent interference. In the end, this paper obtains 3616 sample observations, and the financial data of the sample companies mainly come from the Guotaian (CSMAR) database.

4.2 Variable Definition

4.2.1 Enterprise Green Innovation

The explained variable in this paper is the enterprise's green innovation (GI) . According to the existing literature, green innovation theory

In fact, it can be measured by the input or output of enterprises in green technology innovation. This paper concretizes the abstract concept of green technology innovation as the output of green innovation of enterprises, that is, the number of green patents applied for or authorized by enterprises. However, it often takes a long time from patent application to authorization, so it tends to select the number of applications. Finally, the total amount of green patents obtained by enterprises is used as the measurement index of enterprise green technology innovation.

4.2.2 Environmental Tax

The explanatory variable in this paper is environmental tax (ET). Environmental tax includes 8 tax categories, which are measured by the natural logarithm of corporate environmental tax expenditure. Due to the hysteresis effect of R&D and innovation, the current environmental protection tax may not significantly promote the current corporate technological innovation. Finally, the current environmental protection tax amount of the enterprise, the corporate environmental protection tax amount of the first lagged period, and the environmental protection tax amount of the second lagged period are used as measurement indicators.

4.2.3 Control Variables

In this paper, the following indicators of enterprise characteristics and financial status are selected as control variables: enterprise size

(Size), cash holdings (Cash), asset-liability ratio (Lev), return on total assets

(Roa), capital expenditure (Capital), opportunity cost (TobinQ). In addition, this article selects the corporate governance structure and employee structure: the nature of equity (State), the proportion of independent directors (Id), and the combination of two positions

(Dual), the shareholding of the largest shareholder (Large), and the separation rate of two rights (Sep) are measured as control variables. Select year effect (Year) and industry effect (Industry) as dummy variables so that time and industry changes will not affect the regression results. The definition of each variable can be seen in Table 1 below.

Table 1. Description of main variables

variable name	variable code	variable description
Enterprise Green Innovation	GI	Take the natural logarithm of the sum of the number of green patent applications of enterprises + 1
Current Environmental Tax	AND	The natural logarithm of the corporate environmental tax amount
Environmental protection tax lags behind	L1.ET	The natural logarithm of the corporate environmental tax amount lagged by one period
Environmental protection tax lags behind the second phase	L2.ET	The natural logarithm of the enterprise environmental protection tax amount lagged by two periods
Enterprise size	Size	Natural logarithm of total assets
cash holdings	Cash	Ratio of monetary funds to total assets
Assets and liabilities	Lev	Ratio of total liabilities to total assets
Return On Total Assets	Long	Ratio of net profit to average total assets
Capital expenditures	Capital	Proportion of cash paid for purchase and construction of fixed assets, intangible assets and other long-term assets to total assets
opportunity cost	TobinQ	The sum of the market value of owner's equity and liabilities as a percentage of total book assets
Equity nature	State	State-owned holdings take 1, private holdings take O
Proportion of independent directors	Id	The ratio of the number of independent directors to the number of board members
two jobs in one	Dual	If the chairman and the general manager are not concurrently held by the same person, take 1, otherwise take O
The largest shareholder	Large	Shareholding ratio of the largest shareholder
separation of weights	Sep	The difference between the actual controller's control and ownership of the listed company is expressed
annual effect	Year	Year dummy variable
industry effect	Industry	industry dummy variable

4.3 Model Selection

In order to study the impact of environmental protection tax on corporate green innovation, this paper constructs the following empirical model (1):

$$GIi,t=a0+a1ETi,t+a2L1_Ti,t+a3L2_Ti,t+a4Controlsi,t+b1Yeari,t+b2Stkcdi,t+\varepsilon i,t \quad (1)$$

In the above regression model, the subscripts i and t represent the enterprise and the year respectively. The core explanatory variables are the current ET of the environmental protection tax , L1_ET of the first lag , and L2_ET of the second lag . Controls is the set of control variables, including Size, Cash , Lev , ROA , Capital , TobinQ , state , Id , Dual , Large1, Sep , ε is the random error item of the model. In order to improve the reliability of the regression results, this paper also carried out the following basic treatment: In all the regression equations, the t statistics adjusted by the Cluster

clustering robust standard error are used . In addition, year and industry two-way fixed effects are used.

5. Empirical Analysis

5.1 Descriptive Statistics of Corporate Green Innovation

As can be seen from Table 2 below, the mean value of green innovation GI of the explained variable is 1.104, the standard deviation is 1.132, the minimum value is 0, the maximum value is 4.263, and the median is 0.693. It can be seen that the green innovation level of the sample enterprises varies greatly. The mean value, standard deviation, minimum value, maximum value and median value of environmental tax of explanatory variable ET are 12.263, 3.251, 3.523, 18.069 and 12.6, indicating that the environmental tax burden of sample enterprises presents an unbalanced level. In addition, the statistical values of each control variable are consistent with the mainstream literature, indicating that the variables selected in this paper are reasonable and effective.

Table 2. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
GI	3616	1.104	1.132	0.000	0.693	4.263
AND	3616	12.263	3.251	3.523	12.600	18.069
Size	3616	22.566	1.282	20.171	22.404	26.022
Cash	3616	0.058	0.065	-0.125	0.057	0.250
Lev	3616	0.451	0.197	0.067	0.448	0.900
LONG	3616	0.041	0.064	-0.225	0.038	0.230
Capital	3616	0.303	0.159	0.024	0.283	0.716
TobinQ	3616	1.733	1.007	0.819	1.406	6.586
state	3616	0.418	0.493	0.000	0.000	1.000
Id	3616	0.374	0.053	0.333	0.333	0.571
Dual	3616	0.241	0.428	0.000	0.000	1.000
Largel	3616	0.354	0.148	0.089	0.341	0.764
Sep	3616	5.449	7.823	0.000	0.060	28.136

5.2 Correlation between Corporate Green Innovation and Environmental Protection Tax

Table 3. Correlation analysis

	GI	AND	You are	Cas h	Cap Lev ROA ital			Tob inQ	they are the	Id	Two l	S home and ge1 p	
GI	1												
AND	0.095***	1											
You are	0.494* **	0.447* **	1										
Cas h	0.062***	0.041**	0.086***	1									
Lev	0.2twenty one***	0.338***	0.511***	-0.169* **	1								
LONG	0.007	- 0.081***	- 0.0twenty three	0.442***	-0.4107***								
Cap ital _	0.028*	0.439***	0.217* **	0.197***	0.213***	- 0.144***	1						
Tob inQ	-0.189***	- 0.203***	- 0.378***	0.091***	- 0.266***	0.169***	- 0.157***	1					
sta te	0.131***	0.4twenty one***	0.361***	-0.063***	0.356***	- 0.196***	0.265***	- 0.154***	1				
Id	0.075***	-0.028*	0.029*	0.045***	0.015	0.011	0.008	0.033**	-0.004	1			
Two l	-0.080***	- 0.209***	- 0.181***	0.005	- 0.127***	0.052***	- 0.101***	0.076***	- 0.277***	0.069***	1		
home ge1	0.105***	0.209***	0.2twenty four***	0.083***	0.087***	0.092***	0.105***	- 0.132***	0.262***	0.095***	- 0.073***	1	
Sep	0.038**	0.152***	0.150***	0.056***	0.111***	-0.004	0.158***	- 0.083***	0.018	-0.032*	- 0.062***	0.176***	1

Note: *, **, *** represent significance at 10%, 5% and 1% levels respectively.

As can be seen from Table 3 below, correlation analysis is used to study the correlation between GI and ET, and Pearson correlation coefficient is used to indicate the strength of the correlation. Specific analysis shows that the correlation value between GI and ET is 0.095, showing a significance level of 1%, which indicates that there is a significant positive correlation between GI and ET, and the positive influence of ET on GI needs to be further determined by regression. In addition, the correlation coefficients of all variables are less than 0.5, indicating that the model in this paper does not have multicollinearity problems.

5.3 Benchmark Regression to GI

In order to further verify the impact of ET on GI , this paper conducts regression tests on GI in the current period, the first lagged period, and the second lagged period of ET . The specific regression results can be seen in columns (1), (2), and (3). From the regression results, we can see that the impact coefficients of ET in the current period, lagged first period, and lagged second period are 0.023 , 0.021 , and 0.052 , respectively, which are significantly positive at the levels of 1% , 10% , and 1%, respectively, that is, ET can significantly improve GI . In addition, it can be found that the impact coefficient and t value of L2_ET in the second lagged period are the highest, indicating that the impact of ET on GI is lagging. Generally speaking, enterprises will show a higher level of green innovation in the later stage to cope with environmental protection taxes. Therefore, this hypothesis is proved.

Table 4. Benchmark regression

	(1)	(2)	(3)
	GI	GI	GI
AND	0.023*** (2.78)		
L1_ET		0.021* (1.90)	
L2_ET			0.052*** (3.95)
Size	0.474***	0.481***	0.468***
	(25.47)	(20.68)	(16.81)
Cash	0.339	0.345	0.395
	(1.23)	(0.95)	(0.95)
Lev	-0.005	0.075	0.098
	(-0.05)	(0.60)	(0.64)
LONG	-0.351	-0.027	-0.618
	(-1.19)	(-0.07)	(-1.27)
Capital	-0.401***	-0.393***	-0.458***
	(-3.26)	(-2.61)	(-2.59)
TobinQ	0.016	-0.004	0.025
	(1.01)	(-0.20)	(1.04)
state	0.047	0.042	0.016
	(1.22)	(0.89)	(0.29)
Id	0.615**	0.477	0.293
	(2.21)	(1.39)	(0.73)
Dual	-0.073**	-0.081*	-0.093
	(-2.07)	(-1.74)	(-1.64)
Large1	0.368***	0.717***	0.690***
	(3.24)	(5.04)	(4.03)
Sep	0.002	0.003	0.005
	(1.04)	(1.15)	(1.51)
_cons	-10.159***	-10.402***	-10.524***
	(-26.02)	(-21.47)	(-17.91)
Industry	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	3609	2281	1671
F	117.466	84.667	60.656
R2 -	0.436	0.473	0.469

Note: * , **, and ** represent significant at the significance level of 10% , 5% , and 1% , respectively, and the brackets represent t values, the same below.

5.4 Heterogeneity Analysis of Environmental Protection Tax on Green Innovation

5.4.1 Environmental Tax, Nature of Property Rights and Green Innovation

In order to further verify the moderating effect of the nature of property rights on the impact of ET on GI , this paper conducts group regression according to the nature of enterprise property rights. The specific regression results can be seen in the following table 5. Columns (1), (2), and (3) respectively report the regression results of the state-owned enterprise ET in the current period, the first lagged period, and the lagged second period. The impact coefficients are 0.045 , 0.052 , and 0.090 , respectively. And they are significantly positive at the levels of 1% , 10% , and 1% ; Columns (4), (5), and (6) report the regression results of non-state-owned enterprises, and none of them pass the significance test. The above regression results show that the environmental protection tax has significantly improved the green innovation level of state-owned enterprises, and there is a certain hysteresis effect, but failed to significantly improve the green innovation level of non-state-owned enterprises.

Table 5. Property Rights Adjustment

	(1) State-owned	(2) State-owned	(3) State-owned	(4) Non-state-owned	(5) Non-state-owned	(6) Non-state-owned
	GI	GI	GI	GI	GI	GI
AND	0.045***			0.008		
	(3.08)			(0.77)		
L1_ET		0.052***			-0.009	
		(2.85)			(-0.66)	
L2_ET			0.090***			0.021
			(4.28)			(1.15)
Size	0.556***	0.584***	0.531***	0.387***	0.377***	0.385***
	(18.29)	(15.69)	(12.43)	(14.79)	(10.91)	(8.99)
Cash	0.927**	0.696	0.475	-0.294	-0.310	0.111
	(2.18)	(1.38)	(0.86)	(-0.82)	(-0.60)	(0.17)
Lev	-0.278	-0.314	-0.192	0.328***	0.636***	0.633***
	(-1.64)	(-1.60)	(-0.83)	(2.66)	(3.82)	(2.95)
LONG	-0.842*	-0.832	-0.928	0.266	0.880	-0.240
	(-1.68)	(-1.43)	(-1.32)	(0.73)	(1.64)	(-0.35)
Capital	-0.451**	-0.374*	-0.433*	-0.289*	-0.211	-0.338
	(-2.35)	(-1.74)	(-1.76)	(-1.73)	(-0.97)	(-1.28)
TobinQ	0.041	0.053	0.053	0.007	-0.016	0.023
	(1.44)	(1.38)	(1.33)	(0.33)	(-0.60)	(0.68)
state	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Id	1.275***	1.003**	0.684	-0.249	-0.697	-0.753
	(3.04)	(2.05)	(1.22)	(-0.68)	(-1.45)	(-1.32)
Dual	-0.202***	-0.212**	-0.247**	-0.032	-0.049	-0.050
	(-2.64)	(-2.36)	(-2.41)	(-0.78)	(-0.87)	(-0.69)
Large1	0.464**	0.734***	0.595**	-0.014	0.313	0.323
	(2.52)	(3.38)	(2.38)	(-0.10)	(1.53)	(1.24)
Sep	0.002	0.002	0.004	0.006**	0.009**	0.010**
	(0.49)	(0.71)	(1.00)	(2.17)	(2.25)	(2.06)
_cons	-12.635***	-13.409***	-12.632***	-7.667***	-7.315***	-7.922***
	(-20.47)	(-17.74)	(-14.34)	(-13.37)	(-9.61)	(-8.34)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
N	1504	1088	843	2098	1191	819
F	81.136	65.751	40.994	38.662	23.611	17.871
R2 -	0.535	0.561	0.551	0.380	0.438	0.436

5.4.2 Environmental Tax, Enterprise Scale and Green Innovation

In order to further verify the moderating role of enterprise size in the impact of ET on GI , this paper conducts group regression according to the median of sample enterprise size. The specific regression results can be seen in Table 6 below , columns (1), (2), (3) respectively report the regression results of ET in the current period, the first period of lag and the second period of lag, and their influence coefficients are 0.021 , 0.023 , 0.055 respectively, among which the latter and the second period of ET lag are significant at the level of 1% ; column (4) , (5), (6) Reported the regression results of small-scale enterprises, none of which passed the significance test. The above regression results show that the environmental tax has significantly improved the green innovation level of large-scale enterprises, and the hysteresis effect is particularly obvious in large-scale enterprises, but it has failed to significantly improve the green innovation level of large-scale enterprises.

Table 6. Enterprise Scale Adjustment

	(1) large scale	(2) large scale	(3) large scale	(4) Small scale	(5) Small scale	(6) Small scale
	GI	GI	GI	GI	GI	GI
AND	0.021			0.013		
	(1.59)			(1.26)		
L1 ET		0.023			-0.000	
		(1.44)			(-0.02)	
L2 ET			0.055***			0.028
			(3.10)			(1.28)
Size	0.576***	0.578***	0.569***	0.308***	0.313***	0.292***
	(16.95)	(14.89)	(12.93)	(8.61)	(6.41)	(4.34)
Cash	0.558	0.549	0.318	0.433	0.824*	1.260**
	(1.18)	(1.04)	(0.53)	(1.33)	(1.71)	(2.37)
Lev	-0.091	-0.045	-0.142	0.218**	0.390***	0.478***
	(-0.48)	(-0.20)	(-0.56)	(2.05)	(2.82)	(2.71)
LONG	-0.346	-0.260	-0.960	-0.067	0.222	-0.410
	(-0.60)	(-0.38)	(-1.19)	(-0.20)	(0.46)	(-0.70)
Capital	-0.587***	-0.572**	-0.539**	-0.531***	-0.670***	-0.811***
	(-2.94)	(-2.53)	(-2.16)	(-3.70)	(-3.55)	(-3.37)
TobinQ	-0.009	-0.021	0.010	0.002	-0.027	0.003
	(-0.25)	(-0.49)	(0.22)	(0.09)	(-1.19)	(0.09)
state	0.088	0.061	0.013	0.020	0.040	0.051
	(1.42)	(0.86)	(0.16)	(0.41)	(0.65)	(0.65)
Id	1.394***	0.946*	0.604	-0.191	-0.195	-0.246
	(3.33)	(1.91)	(1.06)	(-0.55)	(-0.42)	(-0.44)
Dual	-0.232***	-0.250***	-0.282***	0.001	0.043	0.082
	(-3.49)	(-3.12)	(-3.11)	(0.03)	(0.78)	(1.16)
Large1	0.632***	0.917***	0.945***	0.022	0.256	0.174
	(3.67)	(4.65)	(4.22)	(0.15)	(1.22)	(0.64)
Sep	0.005	0.006	0.007*	0.003	0.004	0.005
	(1.52)	(1.64)	(1.66)	(1.08)	(1.03)	(1.05)
_cons	-12.885***	-12.905***	-13.019***	-6.034***	-6.088***	-6.042***
	(-17.87)	(-15.47)	(-13.61)	(-7.68)	(-5.68)	(-4.02)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
N	1809	1300	1016	1796	976	648
F	50.076	39.774	31.207	10.911	7.898	4.768
R2 -	0.414	0.448	0.448	0.272	0.334	0.315

5.4.3 Environmental Tax, Financing Constraints and Green Innovation

In order to further verify the moderating role of financing constraints in the impact of ET on GI , this paper measures the financing constraints of the sample companies according to the cash flow level of the sample companies. A company with a better cash flow level represents a stronger financing ability. Therefore, when it is higher than the median of the sample cash flow, it means that the financing constraint is low, otherwise it is high. The specific grouping regression results can be seen in the following table 7. Columns (1), (2) and (3) respectively report the regression results

of the current period, the first lagged period, and the lagged second period of the ET group with high financing constraints , and it can be seen that none of them are significant; columns (4), (5) and (6) reported the regression results of the group with low financing constraints. The influence coefficients of ET current period, lagged first period and lagged second period are 0.029 , 0.031 and 0.062 respectively , and they are all at the level of 1% . Significantly, among them, the impact coefficient of the lagged second period is the highest. The above regression results show that the environmental tax significantly improves the green innovation level of enterprises with low financing constraints, but fails to significantly improve the green innovation level of enterprises with high financing constraints.

Table 7. Financing Constraint Adjustment

	(1) High constraints	(2) High constraints	(3) High constraints	(4) Low constraints	(5) Low constraints	(6) Low constraints
	GI	GI	GI	GI	GI	GI
AND	0.011			0.029***		
	(0.91)			(2.59)		
L1_ET		0.001			0.031**	
		(0.06)			(2.04)	
L2_ET			0.036*			0.062***
			(1.73)			(3.47)
Size	0.504***	0.550***	0.562***	0.436***	0.424***	0.383***
	(18.17)	(15.84)	(13.05)	(16.68)	(13.04)	(9.93)
Cash	0.532	0.654	1.527*	0.178	0.316	0.574
	(0.97)	(0.90)	(1.81)	(0.32)	(0.44)	(0.71)
Lev	-0.176	-0.185	-0.237	0.284*	0.458**	0.614***
	(-1.31)	(-1.05)	(-1.05)	(1.87)	(2.46)	(2.73)
LONG	-0.504	-0.124	-0.579	0.015	0.194	-0.067
	(-1.26)	(-0.23)	(-0.79)	(0.03)	(0.31)	(-0.10)
Capital	-0.525***	-0.464**	-0.390	-0.320*	-0.286	-0.386
	(-2.77)	(-1.98)	(-1.43)	(-1.86)	(-1.38)	(-1.54)
TobinQ	0.043*	0.029	0.071*	-0.001	-0.009	0.015
	(1.72)	(0.93)	(1.86)	(-0.03)	(-0.31)	(0.46)
state	-0.016	-0.063	-0.096	0.134**	0.117*	0.122
	(-0.29)	(-0.88)	(-1.06)	(2.39)	(1.75)	(1.58)
Id	0.648	-0.318	-0.403	0.508	0.977**	0.559
	(1.58)	(-0.63)	(-0.69)	(1.31)	(2.05)	(1.01)
Dual	-0.030	-0.058	-0.067	-0.117**	-0.133**	-0.169**
	(-0.58)	(-0.81)	(-0.77)	(-2.40)	(-2.11)	(-2.16)
Large1	0.473***	0.849***	0.854***	0.308**	0.618***	0.584**
	(2.72)	(3.86)	(3.27)	(2.00)	(3.20)	(2.50)
Sep	0.000	0.002	0.002	0.005*	0.006*	0.007
	(0.02)	(0.60)	(0.50)	(1.82)	(1.71)	(1.60)
_cons	-10.649***	-11.320***	-12.089***	-9.478***	-9.642***	-9.121***
	(-17.92)	(-15.61)	(-13.60)	(-17.33)	(-13.88)	(-10.85)
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
N	1802	1110	786	1798	1164	872
F	53.280	42.235	31.694	66.272	43.766	30.861
R2 -	0.451	0.504	0.522	0.447	0.479	0.455

5.5 Robustness Test

5.5.1 Replace the Explained Variable - The Number of Green Patents of the Enterprise

First of all, this paper replaces the quantity of green patents with the quality of green innovation, and then regresses. Back.

The regression results can be seen in Table 8 below. It can be seen that the influence coefficients of ET current period, lagged first period, and lagged second period are 0.175 and 0.175 respectively .0.226 , 0.360 , both are significantly positive at the level of 1%, and the regression coefficient of the lagged second period is higher than the current period and the lagged first period,

that is, the environmental protection tax can significantly improve the green innovation of enterprises, and the hysteresis effect exists, which verifies the hypothesis of this paper again reliability.

Table 8. Robustness checks

	(1)	(2)	(3)
	giz	giz	giz
AND	0.090* (1.79)		
L1_ET		0.130* (1.94)	
L2_ET			0.287*** (3.45)
cons	-48.690***	-51.132***	-51.285***
	(-16.11)	(-13.26)	(-11.18)
Controls	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	3609	2281	1671
F	32.923	23.843	18.191
R2 -	0.259	0.278	0.288

5.5.2 Replace the Regression Model of the Poisson Panel Fixed Effect Model

Finally, this paper also uses the Poisson panel fixed effect model to perform regression again, and the specific regression results can be seen in Table 9 below. It can be seen from Table 9 that the impact coefficient of the second period of ET lag is 0.032, and it is significantly positive at the level of 1%, indicating that environmental protection tax can significantly improve the green innovation of enterprises, and the hysteresis effect exists significantly, which verifies the robustness of the hypothesis in this paper .

Table 9. Robustness test (replacement regression model)

	(1)	(2)	(3)
	GI	GI	GI
AND	0.008 (1.04)		
L1_ET		0.004 (0.46)	
L2_ET			0.032*** (2.88)
_cons	-9.059***	-8.500***	-8.565***
	(-27.30)	(-21.18)	(-17.69)
Controls	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	3604	2275	1666
Pseudo R^2	0.173	0.175	0.170

5.5.3 Placebo Test of L2_ET on GI Regression

In order to avoid endogeneity problems caused by omitted variables, this paper refers to the practice of Zou Ping et al. (2022), and conducted a placebo test on the regression of L2_ET to GI . The specific method is to randomly mismatch the L2_ET with the full sample, form a new L2_ET_Random , and then regress the GI again. From Figure 1 below, it can be seen that the coefficient of L2_ET_Random takes 0 as the mean value and presents a normal distribution, which deviates from the true influence coefficient of L2_ET of 0.052 . Therefore, L2_ET_Random formed by random mismatch is no longer significant to GI and passed the placebo test. Therefore, the hypothesis of this paper has passed the endogeneity test, and the conclusion is further robust.

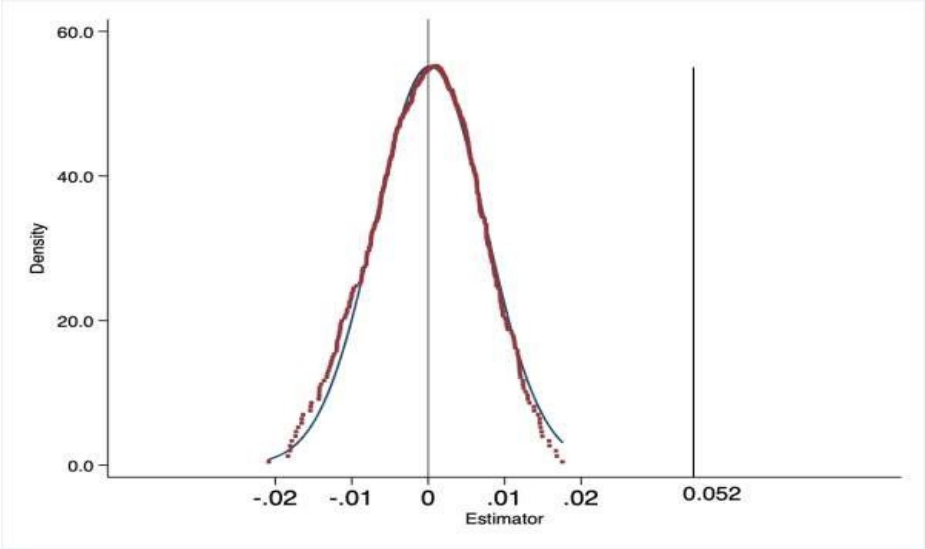

Figure 1. Placebo test

6. Conclusion and Policy Recommendations

This paper adopts a combination of theory and empirical methods, selects Shanghai and Shenzhen A -share listed companies from 2010 to 2020 as research samples, and investigates the impact of environmental protection tax on corporate green innovation and its impact mechanism. The following conclusions are obtained: First, the environmental protection tax significantly improves the green innovation level of state-owned enterprises, but not significantly to private enterprises. Second, the environmental tax can significantly improve the green innovation level of large-scale enterprises, but not significantly for small-scale enterprises. Third, the environmental tax can significantly improve the green innovation level of enterprises with low financing constraints, but not significant for enterprises with high financing constraints.

The conclusions of this paper theoretically enrich the literature on the economic consequences of environmental taxes and the impact of environmental regulation on corporate green innovation, and provide support for improving China's environmental tax system and corporate green innovation capabilities in practice. [4] First, gradually reform and improve the environmental protection tax system. Broaden the scope of collection and management, strengthen collection and management, formulate differentiated environmental protection tax systems, and coordinate the relationship between different types of environmental taxes. Second, expand the number of corporate researchers. Technological innovation activities should focus on talents, and the government should also increase financial subsidies. Third, follow-up and evaluation of reasonable planning policies. Comprehensively improve monitoring capabilities, rationally plan environmental protection tax funds, and appropriately increase environmental quality assessment indicators for local government performance assessments. There are also some deficiencies in this study, mainly in the following aspects: The relevant literature is scarce. Since the environmental protection tax is a relatively new type of tax, the relevant literature may also be limited. Second, the level of research is lacking. Due to the insufficient level of knowledge, the relationship between environmental protection tax and enterprise innovation may not be clarified, and thus there is a lack of comprehensive research on the research questions. [5] Third, data limitations. The data in this article comes from major official annual reports and third-party data such as Wind . However, in statistics, there are problems such as lack of data, non-disclosure, and different statistical calibers, which make the settings of some variables not perfect. On this basis, future research prospects mainly include: first, to further consider the green innovation input indicators of enterprises, and then three-dimensionally examine how environmental protection tax affects the green innovation input of enterprises and the output of green innovation achievements of enterprises; second, to broaden the research perspective , Better identify

the causal effect of environmental taxes on corporate green innovation, and at the same time broaden environmental taxes from the perspective of other stakeholders Research on the Influence Mechanism of Enterprise Green Innovation.

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References

[1] Abbas Jawad, Wang Lisu, Ben Belgacem Samira, Pawar Puja Sunil, Najam Hina, Abbas Jaffar. Investment in renewable energy and electricity output: Role of green finance, environmental tax, and geopolitical risk: Empirical evidence from China[J]. Energy, 2023, 269.

[2] Tang Wenliang, Yang Xue. Is environmental tax legislation effective for pollution abatement in emerging economies? Evidence from China[J]. Frontiers in Environmental Science, 2023.

[3] Xiaomin Zhao, Jiahui Li, Yang Li. Impact of Environmental Tax on Corporate Sustainable Performance: Insights from High-Tech Firms in China[J]. International Journal of Environmental Research and Public Health, 2023, 20(1).

[4] Shen Yang, Zhang Xiuwu. Study on the Impact of Environmental Tax on Industrial Green Transformation[J]. International Journal of Environmental Research and Public Health, 2022, 19(24).

[5] Wang Hui, Wang Yi, Wang Zongxian. Research on the economic impact of environmental tax under the background of state-owned enterprise shareholding reform in an open economic system.[J]. Environmental science and pollution research international, 2022, 29(54).