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Research on the Impact of Environmental Protection Tax on Green Technology Innovation of Enterprises

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Abstract. The environmental protection tax reform implemented since January 1, 2018, occupies a significant position in China's environmental policy framework, and also marks a key practice of China's ecological and environmental protection tax in the new era. It is an important feature of the domestic environmental regulation policy system and an important measure for the implementation of China's ecological and environmental protection tax law in the new era. Against the backdrop of promoting high-quality domestic development strategies, how does this policy affect the motivation to stimulate green technological innovation and what effects does it have on the quantity and quality of green innovation behavior in society as a whole? This study selected A-share listed companies listed on the Shanghai and Shenzhen stock markets from 2014 to 2020 as samples, and used the promotion of environmental protection tax system as a quasi natural experimental scenario. A double difference model was used for empirical analysis to explore the specific impact of environmental protection tax system on the innovation of green technology in enterprises. The research results indicate that the reform of the environmental tax system effectively motivates enterprises to take action in green innovation and improves the quality of their innovation. These research conclusions can provide suggestions and theoretical basis for deepening environmental tax reform, building a market-oriented green technology innovation system, and forming a high-quality innovation intellectual property system.

Keywords: Environmental Protection Tax; Green Technology Innovation; Innovation Activity Quality.

1. Introduction

The report of the 20th National People's Congress of the CPC clearly stated that our country must move towards a beautiful and green future development blueprint, comprehensively adjust and balance the allocation of productive forces, pollution control, environmental protection and many other links, jointly promote the reduction of carbon emissions, pollution, increase of green area and economic growth, and support the construction of a green and low-carbon lifestyle and ecological priority development strategy. The rapid economic growth in our country has led to an increase in demand for energy and an increase in pollutants, putting enormous pressure on the ecological environment. The company is facing a challenge of how to reduce environmental pollution without significantly reducing production efficiency. With technological progress, enterprises can reduce the emission of air pollutants and achieve environmental protection goals while improving production efficiency (CHANHR et al., 2017). Dedicated to environmental technological innovation can help enterprises establish lasting commercial competitive advantages and bring positive effects to their long-term development. Therefore, innovation in green technology plays a decisive role in alleviating the conflict between high energy consumption production and sustainable development. In order to promote the transformation of the ecological civilization system, create a green country that the people of the country long for, and establish a market-oriented environmental protection technology innovation framework, the country made a bold move in development and transformation in April 2019. The National Development and Reform Commission and the Ministry of Science and Technology jointly issued the Guiding Opinions on Building a Market oriented Green Technology Innovation System. This guide further clarifies the specific steps and timetable for implementing a green technology innovation system. This move symbolizes that "ecological friendly technological innovation" has been identified as a key issue in the top-level documents of the Party for the first time,

and has evolved into the basic framework for national policy implementation, which is of great significance for the development of sustainable environmental civilization in China.

Environmental regulations are one of the key ways and tools to encourage companies to implement environmental maintenance measures, which are essential for promoting efficient construction of enterprises (Rugman&Verbeke, 1998). The main forms of environmental regulations include government mandated environmental control and market driven environmental management strategies. Since January 1, 2018, China has implemented a new regulation called the Environmental Protection Tax Law, which was formerly known as the system of collecting pollution discharge fees. After this new law came into effect, several provinces and cities in China have raised the tax standards for pollution emissions, that is, the tax rate of environmental protection tax has increased; However, in order to maintain stable tax burden, some other provinces and cities have balanced the original pollution cost system, making the tax rate of environmental protection tax consistent with the previous level of pollution cost.

Environmental protection tax, as a market-oriented environmental governance mechanism, represents a cornerstone of China's environmental and economic strategy (Guo Junjie et al., 2019). The improvement of this tax system can make the costs of pollution emissions clearer, thereby promoting ecological innovation in the field of environmental protection and pollution control, and playing a crucial role in guiding capital towards more ecologically friendly industries. It has a profound impact on the maintenance and improvement of the environment, pollution reduction, and green industry transformation. Traditionally, environmental regulation in China has focused more on administrative measures, which are implemented through mandatory orders and controls (Tao Feng et al., 2021), which is beneficial in environmental protection and pollution control. However, with the establishment of a market economy system and the emergence of diversified economic entities, relying solely on administrative orders is no longer effective in addressing environmental pollution issues. Although administrative regulations take effect quickly, their implementation costs are high and can easily lead to negative economic and social impacts. In recent years, China has tended to apply market-oriented environmental regulatory measures and guide participants to improve the environment through economic incentives such as taxation, supported by market mechanisms. As an important part of China's environmental policy system as a market-oriented tool, environmental protection tax can stimulate the potential of enterprises to engage in green innovation, becoming a hot topic of discussion and concern at the academic and policy levels. The quantitative identification of its actual impact is a key factor. The collection of environmental protection tax is a significant adjustment from the environmental protection fee system to the tax system, which is actually equivalent to a "natural experiment" conducted in the economic field. This change is extremely valuable as it provides an excellent opportunity to accurately evaluate the role of China's environmental protection tax policy in identifying the green innovation of public enterprises, and helps to collect strong empirical support for exploring this issue.

The issue of how environmental regulations drive companies to innovate in green technologies has long been a hot topic in global academic discussions. Despite numerous in-depth discussions in this field, the academic community has yet to reach a unified view. The Porter Theory (Porter, 1991; Porter&Van der Linde, 1995) suggests that appropriate environmental control strategies (especially the application of market mechanisms) can lead to the phenomenon of "innovation compensation". This is because market-oriented management methods, such as emission taxes or tradable emission quotas and performance indicators, can promote enterprise innovation more than pure technical specifications - mainly reflected in their provision of more flexible choice space, allowing enterprises to have greater autonomy in finding technological solutions, which is conducive to reducing the cost of complying with regulations. Research has shown that strict environmental control has a positive impact on a company's innovation ability (Popp, 2002, 2006; Lovely&Popp, 2011; Jing Weimin&Zhang Lu, 2014; Qi Shaozhou et al., 2018; Li Qingyuan&Xiao Zehua, 2020; Tao Feng et al., 2021). For polluting enterprises, maintaining a high level of green technology innovation and patent quantity can help them maintain competitive advantages and stabilize market share (Popp,

2006). However, some studies have also shown completely opposite conclusions. The research conducted by Requeste&Unold (2001) found that companies actively invest in emerging technologies only when environmental taxes are levied, and in contrast, the effect of auctions or free licenses on promoting innovative capital investment by companies appears to be weak. Subsequently, Brunnermeier&Cohen (2003) conducted a study using manufacturing data from the United States, and the results showed that environmental regulations did not have an additional promoting effect on innovation incentives. Leeuwen&Mohnen (2017) also stated that environmental regulations may hinder the efficiency of technological innovation. Although research evidence in this area is constantly emerging, due to differences in environmental management in different countries, different sample selection and research methods, there is still no consensus on the relevant research results.

These contradictory insights provide two key insights for empirical research: firstly, it is necessary to identify different types of environmental regulations and policies in a targeted manner, even though mandatory environmental regulations and market-based environmental strategies play vastly different driving roles in promoting environmentally friendly technological innovation. Secondly, environmentally friendly technological innovations should be selected from a broad range of innovative behaviors, and their quantity and quality should be accurately evaluated.

Based on the above research, in order to explore the impact of environmental protection tax on the quantity and quality of green technology innovation activities of enterprises, this article attempts to examine the impact of environmental protection tax on China's green technology innovation behavior by distinguishing between the quantity and quality of green patent applications. This study, based on the green patent data of A-share listed companies in Shanghai and Shenzhen from 2014 to 2020, found that the implementation of environmental protection tax not only significantly promoted the increase in the proportion of green patent applications, but also promoted the improvement of green patent quality.

The possible contributions of this article are mainly reflected in three aspects: (1) providing new empirical evidence for the study of the relationship between the implementation of environmental protection tax reform and corporate green innovation. (2) On the basis of existing literature, this article further examines the impact and mechanism of China's basic environmental and economic policies - environmental protection tax law on corporate green technology innovation, enriching the literature on the impact of environmental regulations on corporate green innovation and expanding new research perspectives. (3) In previous literature, when measuring green technology innovation in enterprises, most studies only focused on the impact of the quantity of green innovation activities, and there are relatively few studies on the effect analysis of green innovation activities on their quality. Therefore, this article explores the impact of environmental taxes on corporate green technology innovation behavior by distinguishing the quantity and quality indicators of green technology innovation.

The subsequent structure of this article is as follows: the second part will introduce the institutional background, the third part will conduct theoretical analysis and research hypotheses, the fourth part will elaborate on the research design, the fifth part will present empirical analysis results, and the sixth part will summarize the research conclusions and propose policy implications.

2. Institutional Background

Since China's reform and opening up, its economy has developed rapidly. However, at the same time, the rapid development process has caused problems such as environmental pollution and ecological damage, which have become the main obstacles to sustainable economic development. Faced with the challenge of high-quality economic development, solving environmental pollution problems has become an urgent task.

Until 2018, China had been responsible for collecting taxes on the discharge of harmful substances in the form of "sewage treatment fees". Since September 1979, with the implementation of the

Environmental Protection Law (Trial), the relevant provisions on "cost burden of water quality management" have been incorporated into the legal and regulatory system, symbolizing that we have begun the construction of a legal framework for natural resource management in China. At the end of 1989, our new version of the Environmental Protection Law was released and underwent revision and optimization work. In 2003, relevant departments issued a new regulation, the "Regulations on the Collection and Management of Pollutant Discharge Fees," to further improve regulations on additional expenses incurred in waste disposal. In the early stages of reform and opening up, the pollution fee system was regarded as a key policy for environmental management. However, as China's economy enters a stage of high-quality development, certain shortcomings of the pollution discharge fee system have gradually emerged and are no longer able to adapt to the speed of economic growth. The implementation of "fee to tax" is to achieve the goal of environmental protection, which has become a necessary step in the development process. Starting from January 2018, China's environmental protection tax law will officially come into effect. According to Ge Chazhong (2015), the implementation basis of the "fee to tax" policy is a vertical extension based on the relevant provisions of the Pollution Discharge Fee Regulations, which is an important part of the process of formulating environmental protection tax regulations.

This environmental protection tax reform has achieved a transformation from a pollution discharge fee system to an environmental protection tax, with the following main characteristics: firstly, the legislative level has been elevated. The Environmental Protection Tax Law is the first tax law in China to be reviewed and approved through the principle of statutory taxation. Compared to administrative order based pollution discharge fees, the Environmental Protection Tax has a more effective legal basis and authority, which helps to improve taxpayers' environmental awareness and compliance, and strengthen the responsibility of enterprises to reduce emissions and control pollution. Secondly, the principle of shifting taxes and fees. In the "fee to tax" campaign in China, "tax and fee translation" is regarded as the main criterion and reference point for this reform. After the implementation of the 2018 bill, some regions maintained their original pollution discharge fee standards, while others adopted higher collection standards than the original pollution discharge fee standards. This measure is equivalent to a "natural experiment" conducted in the economic field, with significant exogenous characteristics, providing a rare opportunity to effectively evaluate the impact of China's environmental protection tax on corporate green innovation.

3. Theoretical Analysis and Research Hypotheses

1. The impact of environmental protection tax on the number of green innovation activities of enterprises

The collection of environmental taxes aims to maintain and improve the environment, with the goal of reducing pollution emissions and promoting the development of ecological civilization. It is one of the key environmental market regulation measures adopted by China to promote ecological environment maintenance and implement the strategy of "green mountains and clear waters are as valuable as gold and silver". If carefully designed, this tax may also have a significant effect on promoting green technology innovation.

The implementation of environmental tax sends a signal to the manufacturing industry that its resource utilization in production and operation may not be efficient, and there is still room for technological innovation. In the field of environmental protection in our country, many companies lack sufficient understanding of the total amount of pollutants they discharge, the costs and risks of environmental pollution, and also lack experience in reducing emissions and waste disposal. The introduction of an environmental tax system, especially in areas where tax rates have increased, has strengthened the control of environmental protection and prompted enterprises to recognize the possibility of innovation within these areas, while facing external innovation drivers. According to competition theory, under this external pressure, enterprises can break through their inherent inertia, trigger innovation awareness, and play a core role in innovation actions. Moreover, environmental

regulations have reduced the instability of enterprises in the field of environmental investment, transformed their expectations, and encouraged them to innovate in environmental technology. The increasing environmental tax rate has raised the tax standards for pollutant emissions, bringing significant cost burdens to enterprises and reflecting the government's firm will and policy orientation to protect the environment. This forces companies to realize that ecological security is not just talk or concept, it is a practical issue directly related to the long-term interests of the enterprise. Moreover, compared to other measures such as adjusting production plans, green innovation has a smaller impact on normal production and short-term profits of enterprises (Jaffe&Palmer, 1997; Popp, 2006). In summary, environmental regulation policies such as environmental taxes have established a standardized and fair market competition environment, and enterprises cannot achieve a competitive position by relying on unrestricted pollution emissions. This is extremely beneficial for promoting enterprises to engage in green innovation, especially in the field of clean production.

With the passage of time, a long-term impact on enterprises has emerged: environmental protection taxes are no longer just a temporary shock, but have transformed into a continuous restrictive condition. Whether it is newly established companies or those that have gone through vicissitudes and still exist, investing in green technology innovation has become an self-evident action, further promoting society to embark on the path of green technology innovation, ensuring stable growth in resource input and output of green innovation. Furthermore, the widespread dissemination of environmental taxes and related policies in the media has increased public awareness of environmental protection, forcing academia and research institutions to invest more innovative efforts in the field of the environment. At the same time, the combination of industry, academia, and research has promoted non-profit organizations such as universities and research institutions to actively engage in realistic green technology innovation activities.

Based on this, this article proposes the following assumptions:

H1: The implementation of environmental protection tax has promoted an increase in the number of green technology innovation activities of enterprises.

2. The impact of environmental protection tax on the quality of green innovation activities

The environmental protection tax implemented in China has become a key link in the development strategy of ecological economy and the structure of environmental protection policies. After the introduction of this tax, the tax standards for pollutant emissions have been raised in certain regions, leading to stricter emission limits and increased environmental requirements for enterprises. In the journey of promoting both corporate growth and ecological balance, green technology innovation is seen as a crucial bridge to achieve coordination between the two. In the implementation stage of environmental pollution control, enterprises can adopt various methods to reduce the output of waste, which can be summarized into two main directions: first, innovation from the source, that is, by improving the efficiency of the production process or adjusting production steps, reducing the generation of pollutants from the beginning; The second is a reform measure aimed at the production backend. In cases where it is difficult to implement emission reduction during the product manufacturing process, technology updates for emission reduction will be carried out by introducing or improving exhaust gas treatment equipment, ultimately at the end of production. In the long run, controlling from the source is an important means to reduce environmental burden and move towards sustainable development. However, innovation from the source presents higher level challenges for enterprises, especially in the development of environmentally friendly energy technologies such as biomass and hydrogen. Therefore, enterprises may be more willing to improve the efficiency of traditional fossil energy use or adopt green technology innovation to reduce pollution emissions at the end of the production process. This approach is closely related to China's economic development pattern that still revolves around traditional energy and the path dependence of companies in green reform.

The improvement of the environmental tax system not only increases the tax requirements for unit pollution emissions, but also demonstrates the government's firm will in pollution control. This

change has adjusted the expectations of enterprises, which not only bear the burden of environmental protection tax, but also have to deal with a series of environmental control costs such as strict supervision and corresponding punishment measures after the implementation of the Environmental Protection Tax Law. Therefore, in the face of such strict control measures, polluting enterprises may tend to choose green innovation that creates more value. However, given the high value, long cycle, and other practical limitations of green innovation patents, polluting enterprises may choose to implement strategic innovations in the short term to address the challenges posed by environmental regulations.

At the current stage of development in our country, emissions such as carbon dioxide produced by fossil fuels are the main source of pollution. The improvement of green innovation quality plays a crucial strategic role in promoting the progress of environmental protection and achieving carbon emission balance. Historical research has found that domestic listed companies pay more attention to the quantity of output and neglect its quality in innovation activities (based on Li Wenjing and Zheng Manni, 2016). This study evaluates the quality of green technology innovation using the proportion of green invention patents (Liu Jinke, 2022), and investigates the impact of changes in environmental protection tax policies on the quality of green innovation in enterprises. Green invention patents represent a higher level of technological proficiency, as the technological content of invention patents is higher than that of utility model patents and design patents, which can effectively reduce pollution emissions in the long term and help enterprises maintain or enhance competitiveness in industry competition. According to the principle of maximizing profits pursued by enterprises, as long as the quality improved through innovation can save compliance costs and obtain additional benefits higher than R&D investment, enterprises naturally tend to invest in research and development of high-quality green invention patents to obtain long-term maximum benefits (Hering and Poncet, 2014). Therefore, under the strict requirements of environmental regulations, for polluting enterprises, choosing green core innovation focused on high efficiency is clearly a wiser choice.

Based on this, this article proposes hypothesis 2: the implementation of environmental protection taxes promotes the improvement of the quality of green technology innovation activities in enterprises.

4. Research Design

1. Sample selection and data sources

Green innovation refers to various technologies, products, and processes aimed at reducing pollution emissions and energy consumption. This study focuses on the improvement of environmental protection technology at the company level, and determines the environmental protection patents held by the company based on the International Green Patent Classification Guidelines published by the International Intellectual Property Organization in 2010. The study sampled relevant sector data of A-share listed companies in 31 provinces and cities in China from 2014 to 2020, including environmental protection patent application information and other related financial data, collected from CNRDS and Guotai An databases.

On the premise of ensuring data accuracy, the following measures have been taken: excluding ST * ST and PT sample enterprises; Exclude sample companies with missing main data; Eliminated samples of companies with missing key information; The data was paired, organized, and processed, resulting in a micro level panel dataset covering 7 years and a total of 10592 data points for various enterprises.

2. Variable Description

(1) Dependent variable

The issue of green innovation has received frequent attention in the field of economic research, and numerous literature has approached it from different perspectives, resulting in diverse criteria for evaluating innovative behavior in practical analysis. In the past, measuring a company's green innovation capability often used all of its patents from that year as a substitute indicator. However,

this study borrowed the method of Liu Jinke et al. and selected the proportion of green patent applications in the current period as a tool to quantify the number of green technology innovation behaviors (y1) of enterprises. In other words, the proportion of green patent applications, including green invention and utility model patents, applied by enterprises in the current period to the total number of patents applied for in the same period was compared. Meanwhile, the proportion of applications for green invention patents is used as an indicator to evaluate the quality of green technology innovation behavior (y2) of enterprises.

(2) Explanatory variables

The introduction of environmental protection tax reflects the role of external factors, and the implementation of this policy does not lead to changes in the tax burden of all enterprises. Although this type of taxation is implemented nationwide, the regulations on tax amount vary greatly among different provinces, municipalities, and autonomous regions. In the regions where tax standards have been increased, there are 14 places that have exceeded the previous pollution fee standards, including Beijing, Tianjin, and Hebei; There are 17 regions including Shanghai and Hubei that maintain the original pollution costs unchanged. Therefore, this study drew on the classification methods of Jin Youliang and Yuan Dong, and classified each enterprise based on whether their environmental tax burden had been adjusted before and after policy changes. Enterprises located in areas with increased tax burden were classified as the experimental group, while enterprises with no changes in other tax burdens were treated as the control group. In the study, a dummy variable post_t was set for the implementation of environmental protection tax, with a value of 0 before 2018 and 1 after 2018. For the dummy variable treat_i adjusted for taxable pollutant tax rates in regions, the experimental group (regions with increased tax rates) is marked as 1, and the control group (regions with unchanged tax rates) is marked as 0. This study uses the cross term between post_t and treat_i as the main analytical variable to explain the corresponding phenomenon.

(3) Control variables

Table 1. Descriptive Statistics of Variables

variable	observations	avg	sd	min	max
y1	10592	0.0220	0.0580	0	1
y2	10592	0.0120	0.0400	0	1
size	10592	22.09	1.307	17.95	31.14
lev	10592	0.390	0.197	0.0140	2.290
roa	10591	0.0490	0.0730	-0.957	0.858
cashflow	10592	0.0530	0.0660	-0.450	0.501
fixed	10592	0.204	0.139	0	0.954
growth	10591	0.196	1.144	-0.927	84.99
tobinQ	10385	2.116	1.345	0.715	28.64
listage	10592	1.810	0.910	0	3.434
firmage	10592	2.876	0.301	1.792	4.143

The control variables in this article include: (1) Enterprise size. The scale and volume of a company are more or less related to the probability of achieving research and development results, that is, the larger the company's scale and volume, the higher the probability of successful innovation. (2) List age&Firmage. The innovation potential of companies may be constrained by their establishment time,

and those with a long history are often more likely to accumulate knowledge in research and development, as well as talent resources involved in patent creation. Therefore, relatively speaking, they demonstrate stronger innovation capabilities (Zhang Jie et al., 2015). (3) Capital structure (Lev). The company uses the capital to liability ratio to reflect its capital structure, and by appropriately increasing borrowing without increasing excessive debt costs, it helps to raise capital for new product development, environmental technology development, optimized production processes, and process improvement, solving the problem of long-term capital shortage (Qi Shaozhou et al., 2018). (4) Corporate financial profitability (Roa). In addition, the efficiency of creating value for the company is equally important. Historical studies have shown that the higher the overall return on assets of a company, the stronger its wealth creation and innovation capabilities. Therefore, it is necessary to master and adjust the influencing factors of total asset return rate. (5) Enterprise growth capability. Usually, the stronger the development potential of a company, the more active its business operations are, and the greater the urgency for innovation. (6) Cashflow ratio; (7) Fixed asset ratio (Fixed); (8) Tobin Q value.

The descriptive statistics of variables are shown in Table 1.

3. Model construction

A double difference model (DID) is established by using listed companies from provinces that implement environmental protection tax burden shifting as the control group and listed companies from provinces that implement environmental protection tax burden increasing as the experimental group. The implementation of environmental protection tax policy is regarded as a quasi natural experiment. By comparing the differences in impact between the experimental group and the control group after policy implementation, factors that do not change over time and cannot be observed are eliminated. Within this analytical framework, we use the differences between the experimental group and the control group, as well as the changes before and after implementation, to evaluate the impact of environmental protection tax policy on enterprises. Specifically, we use the results of the experimental group of enterprises as an estimate of policy effects, in order to determine the impact of policies on the quantity and quality of green technology innovation activities. This method helps to eliminate the interference of other potential factors, enabling us to more accurately evaluate the actual effectiveness of environmental protection tax policies, and thus obtain the net effect of policy implementation. The specific model construction is as follows:

$$Y_{it}=\alpha_0 + \alpha_1 treat_i * post_t + \lambda_i + \mu_t + \rho X_{it} + \varepsilon_{it} \quad (1)$$

Among them, the subscripts i and t correspond to the enterprise and year respectively. Given that green invention patents have more prominent advantages in creativity compared to utility model and design patents, and can more accurately map the degree of technological development (Fu Mingwei et al., 2015). Therefore, the dependent variable Y_it represents the proportion of green patent applications (including green invention patents and green utility model patents) by listed companies to the total number of patent applications in the current period, and the ratio of green invention patent applications by listed companies to the total number of patent applications in the current period is used to measure the quantity and quality of green innovation by enterprises. The grouping variable treat_i is a dummy variable that determines whether enterprise i belongs to the experimental group. If enterprise i belongs to the region where the tax standards for taxable pollutants have been increased, that is, the experimental group region, then treat_i=1; otherwise, treat_i=0. The post_t variable is used to distinguish the situation before and after the implementation of the environmental protection tax system. Once t represents 2018 or a subsequent time point, the corresponding post_t value is 1, otherwise it is set to 0. λ_ I and μ_ T is the fixed effect of the enterprise and the fixed effect of the year, respectively. In addition, this study is based on the current model framework and incorporates the control variable X_it that may affect a company's patent application activities, covering factors such as the size of the enterprise, its maturity, capital structure, and financial profitability. The focus of this study is particularly on testing the parameters of the interaction term treat_i [* post] _ t α_ The

valuation of 1 directly reflects the effectiveness of the policy. When α_ 1> 0 indicates that this policy has a positive impact on increasing the number of green patents and improving their quality; On the contrary, α_ If 1<0, it indicates that this policy hinders the improvement of the quantity and quality of green patents. If α_ If 1=0, it indicates that the policy has no significant effect in these areas.

5. Empirical Analysis Results

(1)Empirical results

This article examines the impact of the implementation of environmental protection tax reform on the quantity, quality, and effectiveness of green technology innovation activities in enterprises. The standardized regression test results using Double Difference Analysis (DID) are shown in Table 2. Among them, in columns (1) and (2) of the table, the model did not include fixed effects at the company level and fixed effects in time series; And in columns (3) and (4), the model includes the two fixed effects mentioned above. From the results in columns (1) and (2) of Table 2, it can be seen that the estimated coefficients of the key explanatory indicator treat * post are positive and significant at a 99% confidence level. After further adjustment for fixed effects, the analysis results in columns (3) and (4) also confirm that the coefficients of this indicator remain robust and significantly positive at a 95% confidence level. This indicates that the reform of environmental protection tax has had a significant positive promoting effect on enhancing the activity and quality of enterprises in the field of green innovation in areas with heavy tax burdens.

Table 2. Regression Results of Environmental Protection Tax and Enterprise Green Technology Innovation Benchmark

variable	y1	y2	y1	y2
Treat*post	0.0162***	0.0112***	0.00340**	0.00241**
	(13.10)	(12.99)	(2.435)	(2.097)
size	0.00790***	0.00586***	-0.00222	0.00172
	(13.53)	(14.41)	(-1.471)	(1.383)
lev	0.0130***	0.00512**	-0.0106**	-0.00999**
	(3.501)	(1.983)	(-2.232)	(-2.553)
roa	0.0107	-0.00106	0.0144**	0.00365
	(1.129)	(-0.160)	(2.049)	(0.632)
cashflow	-0.0548***	-0.0313***	-0.0150**	-0.0122**
	(-5.703)	(-4.670)	(-2.114)	(-2.097)
fixed	-0.0140***	-0.0155***	-0.000672	0.00104
	(-3.326)	(-5.251)	(-0.0955)	(0.179)
growth	-0.000265	-0.000352	4.60e-06	-4.59e-05
	(-0.542)	(-1.032)	(0.0122)	(-0.147)
tobinQ	0.00357***	0.00237***	0.00173***	0.00146***
	(7.794)	(7.426)	(4.142)	(4.246)
listage	-0.000757	-0.00293***	0.00400**	0.00108
	(-0.963)	(-5.345)	(2.481)	(0.812)
firmage	-0.0142***	-0.00429***	-0.0400***	-0.0208**
	(-7.009)	(-3.040)	(-3.506)	(-2.215)
Constant	-0.123***	-0.106***	0.177***	0.0314
	(-9.248)	(-11.42)	(3.985)	(0.857)
Observations	10,383	10,383	9,801	9,801
R-squared	0.052	0.049	0.716	0.589
corporate effect	NO	NO	YES	YES
year effect	NO	NO	YES	YES

Note: * * *, * *, * * respectively represent significance levels of 1%, 5%, and 10%, as shown in the table below.

(2)Parallel trend test

The basic assumption for applying the double difference analysis model relies on the common trend theory, which means that before implementing relevant policies, the control group and the experimental group show a consistent development trend in the number and quality of green innovation activities. That is to say, if not affected by external policy intervention, the dependent variable of the experimental group should maintain a synchronous time series development pattern with the control group. This study referred to the research techniques of Jacobson et al. (1993) and Desch ê nes et al. (2017), and used time series analysis techniques to construct the following regression model:

$$Y_{it}=\alpha_0+\sum_{k=-3}^{3}\alpha_t\ treat_i*u_k+\lambda_i+\mu_t+\rho X_{it}+\varepsilon_{it} \quad (2)$$

In model (2) above, the fictional indicators at different time periods are represented by u_k, while α_ T is used to characterize the differential changes exhibited by enterprises in the control and experimental groups during the relevant time span before and after the reform of the environmental protection tax system. The study uses the period before policy implementation as the benchmark, and the subscript k represents the number of time units away from the benchmark (where k=1 maps to the subscript number 0 in Figure 3, k=2 maps to post1 in Figure 3, k=3 maps to post2 in Figure 3, k=-1 maps to pre2 in Figure 3, k=-2 maps to pre3 in Figure 3, and k=-3 maps to pre4 in Figure 3). The specific results of regression analysis are shown in (1) and (2) of Figure 3. By examining (1) and (2) in Figure 3, it can be concluded that the interaction term before policy implementation was not significant, which means that the interaction effect did not show statistical significance before the implementation of environmental protection tax law. This indicates that before policy implementation, the performance trends of the experimental group and the control group showed a parallel state, satisfying the parallel trend. Furthermore, it can be observed from the graph that the coefficient evaluation results of the interaction term show significance at the 1% level during the year and after the implementation of the Environmental Protection Tax Law. Therefore, based on the above analysis, it can be inferred that before the implementation of the environmental protection tax law, the data of the experimental group and the control group showed the expected parallel trend consistency.

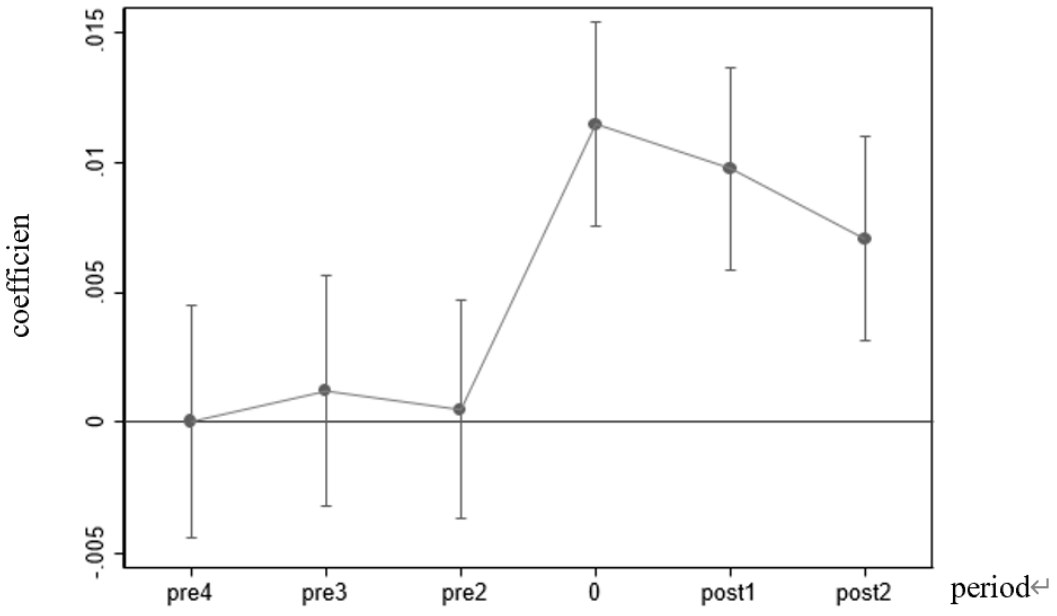

Figure 1. (1) Parallel Trend Hypothesis Test (y1)

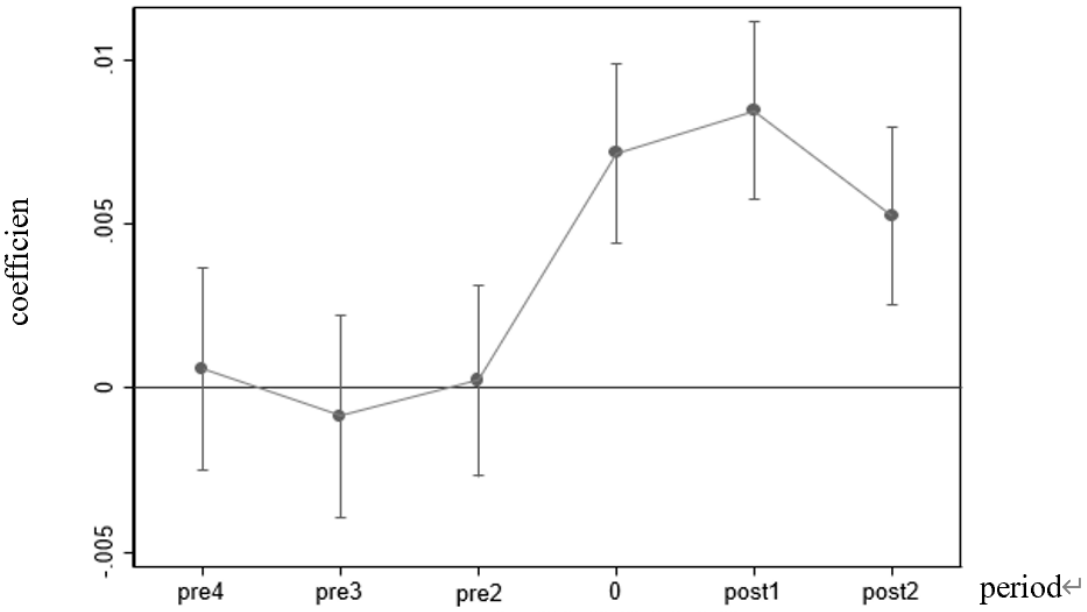

Figure 1. (2) Parallel Trend Hypothesis Test (y2)

(3)Robustness testing

1. placebo test

In order to verify that the impact of DID policy on y1 and y2 is not caused by other random factors, this study used a placebo test to identify the randomness of DID variables. According to the distribution of DID variables in benchmark regression, randomly sample 500 times to construct a "pseudo policy dummy variable", and re estimate the regression using Model (1) to test its coefficients and P-value distribution. The results are shown in the following figure. The mean regression coefficient of the pseudo policy dummy variable is close to 0 and much smaller than the benchmark regression coefficient, and the distribution of the estimated coefficient is close to a normal distribution; The vast majority of P-values exceed 0.10 (i.e., most of the sample data is above the warning line of 0.1), which is not statistically significant at the 10% confidence level, and the policy coefficients are outside the confidence interval of pseudo policy sampling (on the right). This indicates that the impact of DID strategy on y1 and y2 is not caused by other random factors, and the conclusions obtained in the previous section are reliable.

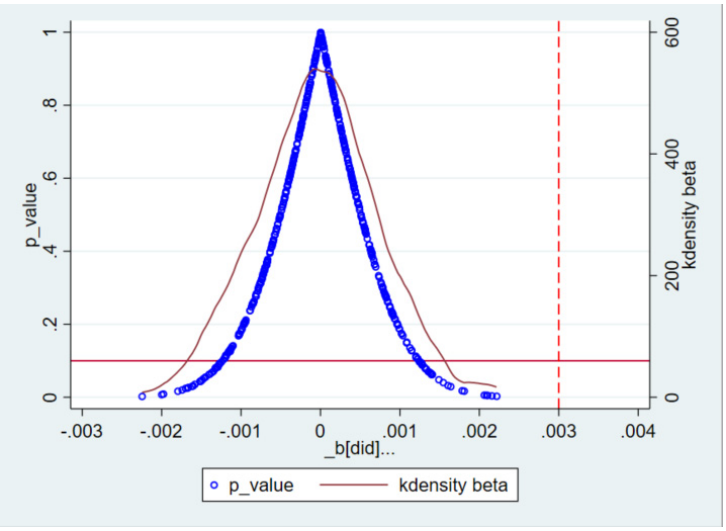

Figure 2. (1) Regression results of placebo test (y1)

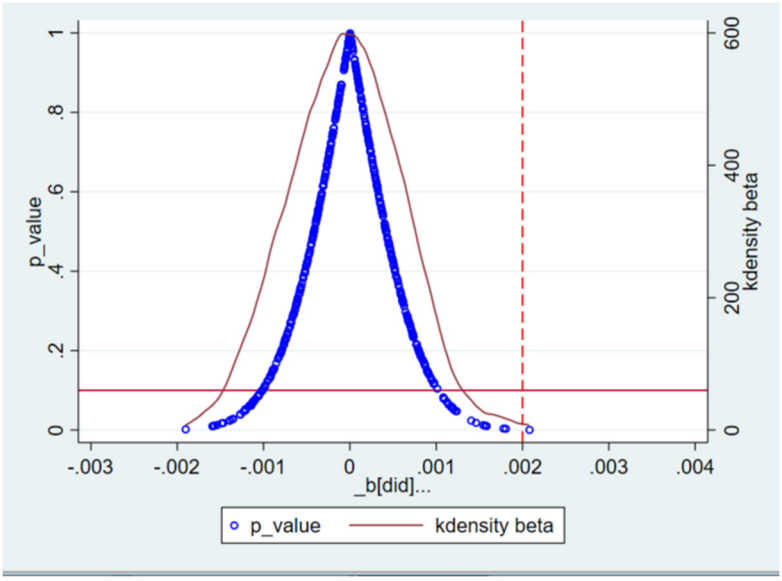

Figure 2. (2) Regression results of placebo test (y2)

2. Replace the dependent variable

In the basic regression, the total proportion of green patent applications is used to measure the degree of green innovation. Considering that this measurement indicator in the benchmark regression is a relative quantity, in order to improve the robustness of empirical analysis, this section replaces the measurement indicator of enterprise green innovation degree with an absolute quantity and selects the number of enterprise green patent applications to measure enterprise green technology innovation for robustness testing. The reanalysis results are shown in Table 3. The results show that the DID policy variable is still positively significant for the dependent variable at a significance level of 5%. This regression conclusion, through robustness testing, strengthens the robustness of the regression results in this article.

(4)Heterogeneity analysis

1. Analysis of the Heterogeneity Impact of Environmental Protection Tax on Regional Differences

After China initiated its reform and opening-up policies, the coastal eastern region has continued to lead the wave of domestic reform and economic development. Decades of steady development have made the eastern region far ahead of the central and western regions in terms of economic infrastructure, commercial market conditions, industry layout, and policy and regulatory concepts. The implementation of the environmental protection tax system is expected to have different impacts on the eastern and central western regions. According to the regression analysis data in Table 5, the policy impact of environmental protection tax in the central and western regions significantly promoted the patent output of enterprises. The double difference method (DID) proved a positive effect on the number of patents of enterprises at a significance level of 5%, while in the eastern region, this policy failed the significance test; As for indicator y2, the implementation of environmental protection tax has triggered a significant positive effect on enterprise patent output in the eastern region, and the results of the double difference method (DID) have been confirmed at a significance level of 10%. On the contrary, this policy has not shown significant effect in the central and western regions.

After analysis, it was found that in terms of increasing green technology innovation, environmental protection taxes have significantly stimulated companies in the central and western regions compared to companies in the eastern regions. This may be due to the late start of enterprises in the central and western regions, with less investment in green technology innovation in the past. Under the influence of the advantages of latecomers, the implementation of environmental protection tax has resulted in lower investment costs for enterprises in the research and development of environmental protection

innovation technologies. At the same time, there is an urgent need for such innovation, making environmental protection tax play a more prominent role in promoting green technology progress in enterprises in the central and western regions.

Table 3. Robust regression results for replacing the dependent variable

	Green
did	1.289**
	(2.53)
size	1.248**
	(2.27)
lev	-2.873*
	(-1.66)
roa	-0.704
	(-0.28)
cashflow	-5.196**
	(-2.01)
fixed	1.605
	(0.63)
growth	-0.0257
	(-0.19)
tobinQ	0.497***
	(3.26)
listage	-1.535***
	(-2.61)
firmage	-17.24***
	(-4.14)
individual fixed effects	YES
year fixed effect	YES
_cons	28.94*
	(1.78)
N	9801

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

On the other hand, given the level of economic development in the eastern region and the accumulated R&D and innovation experience of enterprises over the years, they have a certain foundation and ability for innovation. Therefore, environmental protection tax has a more significant effect on improving the quality of green technology innovation in eastern companies. In summary, the impact of environmental taxes on enterprises in the eastern and central western regions shows certain differences.

Table 4. Heterogeneity Regression Results in Different Regions

	(1) Eastern region	(2) Midwest region	(3) Eastern region	(4) Midwest region
	y1	y1	y2	y2
did	0.00275	0.00441**	0.00258*	0.00135
	(1.54)	(2.39)	(1.76)	(0.90)
size	-0.00151	-0.00536**	0.00138	0.00193
	(-0.80)	(-2.57)	(0.89)	(1.13)
lev	-0.0167***	0.00449	-0.0159***	0.00425
	(-2.75)	(0.74)	(-3.18)	(0.85)
roa	0.0138	0.0219**	0.00314	0.00879
	(1.58)	(2.14)	(0.44)	(1.05)
cashflow	-0.0195**	0.000661	-0.0154**	-0.00342
	(-2.19)	(0.07)	(-2.10)	(-0.45)
fixed	-0.00247	0.00504	0.000522	0.00428
	(-0.27)	(0.57)	(0.07)	(0.59)
growth	-0.0000587	0.000723	0.000110	-0.000504
	(-0.09)	(0.59)	(0.21)	(-0.50)
tobinQ	0.00193***	0.00112*	0.00158***	0.00116**
	(3.76)	(1.89)	(3.73)	(2.39)
listage	0.00389*	0.00532**	0.00130	0.00179
	(1.96)	(2.21)	(0.80)	(0.91)
firmage	-0.0317**	-0.0773***	-0.0147	-0.0480***
	(-2.30)	(-4.44)	(-1.29)	(-3.36)
individual fixed effects	YES	YES	YES	YES
year fixed effect	YES	YES	YES	YES
_cons	0.141**	0.344***	0.0233	0.0967*
	(2.56)	(5.39)	(0.51)	(1.85)
N	7449	2287	7449	2287

Note: *, * *, and * * * respectively indicate significant at the 10%, 5%, and 1% levels, with robust standard errors in parentheses.

2. Heterogeneity analysis of environmental protection tax on enterprise scale

Due to differences in development stages, technological research and development capabilities, and market competitiveness, various enterprises face varying effects of environmental tax system (ETR) reforms. This study adopts the median of total assets of enterprises as the distinguishing criterion, dividing the participating enterprises into two groups. Enterprises above this criterion are defined as large enterprises, while those below this criterion are recognized as small enterprises. Next, a more in-depth analysis was conducted on the differences in the impact of ETR reform on companies of different sizes. Research has found that for y1, the implementation of environmental protection tax policies has a more significant impact on the number of green innovations in large-scale enterprises.

DID shows a positive promoting effect on the number of green innovations in enterprises at a significance level of 1%, while green innovation activities are positive but not significant in small-scale enterprises; For y2, the implementation of environmental protection tax policy has a more significant impact on the quality of green innovation in enterprises in large-scale groups, and DID shows a positive promoting effect on the quality of green innovation in enterprises at a significance level of 1%. However, the improvement in innovation quality for small companies has not reached statistical significance. Therefore, it can be seen that environmental tax policies have effectively promoted the progress of large companies in green technology innovation, but small companies limited by financial resources and technological strength face challenges in promoting green technology innovation in the current global economic downturn.

Table 5. Heterogeneity Regression Results of Different Enterprise Sizes

	(1) Large scale	(2) Small scale	(3) Large scale	(4) Small scale
	y1	y1	y2	y2
did	0.00674***	0.000768	0.00453***	-0.000281
	(3.10)	(0.41)	(2.66)	(-0.17)
lev	-0.00908	-0.00746	-0.00671	-0.00587
	(-1.12)	(-1.24)	(-1.05)	(-1.08)
roa	0.0212*	0.0103	0.00961	0.00407
	(1.82)	(1.13)	(1.05)	(0.50)
cashflow	0.000853	-0.0302***	0.00251	-0.0258***
	(0.08)	(-3.39)	(0.29)	(-3.21)
fixed	-0.00971	0.00760	-0.0101	0.00473
	(-0.85)	(0.85)	(-1.13)	(0.59)
growth	-0.000431	0.000396	-0.000123	0.000241
	(-0.61)	(0.33)	(-0.22)	(0.22)
tobinQ	0.000914	0.00171***	0.000637	0.00177***
	(1.03)	(3.61)	(0.92)	(4.13)
listage	0.00307	0.00178	0.000477	0.00141
	(0.88)	(0.91)	(0.18)	(0.80)
firmage	-0.0389**	-0.0253	-0.0343**	-0.00876
	(-2.06)	(-1.56)	(-2.33)	(-0.60)
individual fixed effects	YES	YES	YES	YES
year fixed effect	YES	YES	YES	YES
_cons	0.134**	0.0817*	0.115***	0.0292
	(2.53)	(1.80)	(2.76)	(0.71)
N	4866	4583	4866	4583

Note: *, * *, and * * * respectively indicate significant at the 10%, 5%, and 1% levels, with robust standard errors in parentheses.

3. Heterogeneity analysis of environmental protection tax on different wealth creation capabilities of enterprises

Due to the difference in the return on total assets of enterprises, it means that the financial profitability is different, which will lead to different innovation awareness and the impact of the implementation

of environmental protection tax reform will also be different. Grouped by the mean ROA of enterprises, they were divided into two groups: high and low ROA. The results showed that for y1, the impact of environmental protection tax policy implementation on the number of green innovations of enterprises was more significant in the group with low ROA. DID showed a positive promoting effect on the number of green innovations of enterprises at a significance level of 1%, while enterprises with high ROA did not pass the significance test; For y2, the implementation of environmental protection tax policies has a more significant impact on the quality of green innovation in enterprises in the low ROA group. At a significance level of 1%, the implementation of environmental protection tax policies has a positive promoting effect on the quality of green innovation in enterprises, while it has not passed the significance test in the high ROA group. This indicates that environmental protection taxes effectively promote the level of green technology innovation in low ROA enterprises, while high ROA enterprises may have a lower demand for green technology innovation due to their own technological capabilities having developed to a certain extent and causing less pollution to themselves.

Table 6. Heterogeneity Regression Results of Wealth Creation Ability of Different Enterprises

	High roa	Low roa	High roa	Low roa
	y1	y1	y2	y2
did	-0.0000870	0.00667***	0.000593	0.00444**
	(-0.05)	(2.85)	(0.42)	(2.40)
size	-0.000220	-0.000940	0.00488***	0.00212
	(-0.10)	(-0.39)	(2.82)	(1.11)
lev	-0.0137**	-0.0159**	-0.0128**	-0.00943*
	(-2.02)	(-2.38)	(-2.27)	(-1.78)
cashflow	-0.0106	0.00724	-0.0158**	0.00789
	(-1.24)	(0.62)	(-2.24)	(0.86)
fixed	0.00802	-0.0101	0.00706	-0.00340
	(0.84)	(-0.94)	(0.90)	(-0.40)
growth	0.000982	-0.000224	0.000594	-0.000300
	(0.97)	(-0.32)	(0.71)	(-0.53)
tobinQ	0.00131***	0.00133	0.000185	0.00225***
	(3.02)	(1.54)	(0.52)	(3.29)
listage	0.000638	0.00332	-0.000454	0.000360
	(0.38)	(0.87)	(-0.33)	(0.12)
individual fixed effects	YES	YES	YES	YES
year fixed effect	YES	YES	YES	YES
_cons	0.0220	0.0409	-0.0936**	-0.0369
	(0.48)	(0.76)	(-2.50)	(-0.87)
N	4254	4831	4254	4831

Note: *, * *, and * * * respectively indicate significant at the 10%, 5%, and 1% levels, with robust standard errors in parentheses.

6. Research Conclusion and Policy Implications

1. Research conclusion

As China enters a new era of high-quality development, the green development strategy is seen as the core breakthrough to promote efficient economic growth in this transformation process. In this context, the leading role of green innovation technology has become the fundamental driving force for promoting sustainable development. Looking ahead to the future, green technological innovation is undoubtedly a key element in controlling greenhouse gas emission reduction expenses, and also a core support for ensuring the achievement of carbon emission peaks and carbon balance goals and social and economic progress. In recent years, China has actively promoted the reform of environmental protection tax. There is still insufficient research on whether this far-reaching ecological policy reform can effectively motivate enterprises to carry out more green innovation practices, and improve the effectiveness and value of innovation. This study used the double difference method to examine companies at the micro level, analyzing how the environmental protection tax reform specifically affects the innovation activities of green technology in companies, and conducting in-depth discussions and analysis on the quantity and quality of innovation activities. The research concludes that: (1) the implementation of environmental protection tax reform has effectively promoted green technology innovation activities in enterprises, and the number of green technology innovation activities in enterprises has increased; (2) The implementation of environmental protection tax reform has effectively promoted enterprise green technology innovation activities, and the quality of enterprise green technology innovation activities has been improved.

2. Policy implications

Based on the above conclusions, the following insights can be obtained:

a. Adhere to the concept of innovative development, deeply understand the key needs of the new era, and enhance the role of current environmental tax policies in guiding and incentivizing green reform. During the critical transformation period of the 14th Five Year Plan, China's ecological environment governance has reached a critical juncture. This stage aims to promote the comprehensive transformation of the economy and society towards green and sustainable direction, with a focus on improving efficiency through pollution reduction and carbon reduction, and shifting the expansion of ecological environment quality towards depth and quality improvement. Developing green and low-carbon technologies has become the core support for China to achieve its dual goals of carbon peaking and carbon neutrality, as well as high-quality growth. Research has revealed that environmental taxes are an effective green fiscal tool for promoting enterprises to pursue green development, playing an indispensable role. The current environmental tax only applies to atmospheric pollutants such as sulfur dioxide and nitrogen oxides, water pollutants, solid waste, and sound pollution, and has not yet covered carbon dioxide emissions, making it difficult to achieve a synergistic effect of pollution reduction and carbon reduction. It is recommended to add a carbon dioxide tax within the environmental tax framework and levy it at an appropriate time. This will encourage enterprises, especially in the new energy industry, to accelerate innovation and work in synergy with carbon emission trading mechanisms, thereby fundamentally promoting the dual reduction of pollution and carbon emissions.

b. Improve the environmental protection tax system. Strengthen the collaborative work between ecological environment institutions and financial and tax authorities, and use the establishment of information sharing mechanisms or the selection of ecological environment workers to enter financial and tax authorities for regular information exchange to promote better cooperation results. Enhance transparency in the use of tax and environmental protection funds, and encourage producers to be more proactive in maintaining the environment. Innovate tax management methods, improve the accuracy of environmental monitoring and the effectiveness of tax inspections, and enhance the supervision and participation of the public. At the same time, promote the widespread adoption of emission permit systems by enterprises, requiring them to comply with established emission standards, self monitor and establish corresponding emission records, and regularly disclose relevant information to the society. Optimize tax reduction and exemption policies for enterprises that do not meet standards, fully leverage the driving function of environmental taxes, and encourage enterprises to actively invest in pollution control actions.

c. Improve the financial and tax policy system guided by green innovation. According to the Opinion (Guofa [2021] No. 4), it is necessary to stimulate the dominant position of enterprises in innovation to the greatest extent, and it is urgent to establish a strong political guarantee mechanism including finance, taxation, etc., to alleviate the resource constraints faced by enterprises in green innovation. The primary task is to reduce the direct control and administrative means of environmental management at the macro level, while improving the effectiveness of market-oriented measures such as environmental regulations, regulations, and norms in implementation. Furthermore, economic incentive policies should be actively adopted, and autonomous participation policies that can stimulate enthusiasm should be formulated to enhance the internal driving force of social and economic development. Finally, policies to promote green technology will be introduced to encourage manufacturing enterprises with high pollution levels to explore new resources, research the application of new materials, clean production processes, environmental pollution treatment technologies, and the recycling and reuse of waste. These highly polluting enterprises will rely on their technological advantages to become the backbone of pollution control, promoting the transformation of China's economy towards high-quality development.

3. Research Shortcomings and Prospects

This article uses panel data from 31 provinces and cities in China from 2014 to 2020 of A-share listed companies in Shanghai and Shenzhen as research samples to empirically analyze the impact of environmental protection tax reform on green technology innovation in enterprises, and further measure and explore the effectiveness of green innovation activity quality. However, limited by the boundaries of time and strength, this paper still has certain limitations and room for further research. The article focuses on 31 provincial-level administrative regions in China, and future research can broaden its perspective to the urban level and provide a more detailed analysis of the composite elements (paths) that promote efficient green technology innovation; Furthermore, the time interval selected in the paper is seven years from 2014 to 2020, and there is potential for further research to expand to a longer time range for empirical exploration.

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