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The unintended consequences of environmental tax for green innovation: evidence from China

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ABSTRACT

Can all types of tax burdens negatively affect corporate innovation activities? The Chinese Environmental Protection Tax Law provides a chance to investigate the impact of environmental taxes on corporate green innovation. Using a large sample of Chinese listed firms for the 2015–2019 period and the difference-in-difference method, this paper finds that environmental taxes promote corporate green innovation. This result is robust to a battery of sensitivity tests and is more prominent for firms facing intense product market competition, firms with more financial constraints, and firms located in lower marketization regions. Mechanism tests find that firms engage in green innovation to cater to government environmental governance. Additional analyses find that environmental taxes have a significant effect on green innovation efficiency and green utility model innovation but fail to impact green invention innovations. Our study provides new and different evidence of the impact of taxes on corporate innovation and has important policy implications.

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KEYWORDS

Environmental tax; Chinese Environmental Protection Tax Law; green innovation; China

1. Introduction

Environmental issues make sustainable development and a circular economy more attractive (Khurshid & Deng, 2021; Khurshid et al., 2022, 2023). Green innovations are regarded as an essential way to address environmental exchange and achieve sustainable development (Greco et al., 2022; Khurshid et al., 2023; Stojcic, 2021; Wang et al., 2023). Market failures, however, may result from underinvestment in innovation activities, such as unpriced knowledge spillover and financing constraints for innovation (Hall & Lerner, 2010; Nelson, 1959). In addition to market failures, firms also have less incentive to develop green innovation because using green technology in production can increase cost, given the higher price of many renewable energy resources and technologies (Roe et al., 2001). Although firms can improve product prices to balance the increase in product costs, whether consumers are willing to pay a premium price for green products is doubtful (Michaud & Llerena, 2010), and consumers simply consider that either the government or the firm should bear the costs and

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burden of social responsibility (Jiang & Kim, 2020). To promote corporate green innovation, government policies play a significant role (Atanassov & Liu, 2020; Chen et al., 2021; Crespi et al., 2016; Hu et al., 2021; Ivus et al., 2021; Stucki et al., 2018).

Taxes are one of the important ways for governments to intervene in corporate innovation activities (Hall, 2021). Many studies suggest that tax reduction can stimulate innovation input and innovation outputs (Chen & Yang, 2019; Crespi et al., 2016; Czarnitzki et al., 2011; Howell, 2016; Ivus et al., 2021; Wang & Kesan, 2022); in contrast, increasing taxes impedes corporate innovation (Atanassov & Liu, 2020; Li et al., 2021). However, Karydas and Zhang (2019) develop a model and propose a different view that increasing environmental taxes may promote technological innovation. Therefore, The Chinese Environmental Protection Tax Law, enacted in 2018, provides an excellent opportunity to examine the impact of environmental taxes on corporate innovation. In this paper, we investigate the impact of the Chinese Environmental Protection Tax Law on corporate green innovation.

Following Amore and Bennedsen (2016), Yu et al. (2021), and Hu et al. (2021), we use the number of green patents plus one to measure corporate green innovation. We adopt the difference-in-difference (DID) method to identify the causal relationship between environmental taxes and corporate green innovation because the Chinese Environmental Protection Tax Law can be regarded as a quasi-natural experiment. Following Tu et al. (2020), we divide a firm into the treated group when the firm belongs to the industry that is defined as heavily polluting by the Guidelines for the Disclosure of Environmental Information for Listed Companies issued by the Ministry of Environmental Protection of China in 2010. Using a large dataset of all Chinese listed firms for the 2015–2019 period, we document extensive evidence that environmental taxes are positively related to corporate green innovation. This evidence is robust to changing the measure of green innovation, excluding samples with zero patents, controlling the effect of air quality, and testing the parallel trend assumption of the DID method.

The association between environmental taxes and corporate green innovation supports the view that firms cater to government environmental determination to obtain more resources and opportunities. To identify the economic mechanism, we investigate whether the relationship between environmental tax and corporate green innovation has heterogeneity in different ownership structures. In China, firms can be divided into two ownership types, namely, state-owned enterprises (SOEs) and non-SOEs. SOEs are controlled by the government and are one of the important ways for the government to intervene in the economy. Compared to non-SOEs, SOEs have a natural close relationship with the government due to ownership and can easily access more resources, such as larger shares of bank credits (Hu et al., 2021; Lin et al., 2020). Therefore, non-SOEs have more incentive to cater to government environmental intention than SOEs. Our results show that the relationship between environmental taxes and corporate green innovation remains statistically significant in the non-SOE subsample, indicating that firms engage in green innovation to cater to government environmental governance.

We also conduct a set of cross-sectional heterogeneity discussions. First, fierce product competition makes firms strongly demand government help to obtain advanced advantages, and we should observe that the impact of environmental taxes on green innovation is more prominent in industries with fierce product competition. Second, firms facing more financing constraints need more bank credit to operate. Meanwhile, the bank sector in China is controlled by the government,

meaning that firms facing more financing constraints should conduct more green innovation. Finally, the marketization process in different regions is uneven across China. Higher marketization makes firms less dependent on the government and have less incentive to engage in green innovation. Our results show that the association between environmental taxes and corporate green innovation is more prominent for firms with fierce product competition, firms with more finance constraints, and firms located in regions with lower marketization.

According to Chinese patent law, patents are divided into three types, namely, invention patents, utility model patents, and design patents. Invention patents have the highest innovation content, as they cover novel technologies. Utility model patents have fewer novel technologies and cover the new application of existing technologies. Design patents cover product shapes and have very limited technological advancement. Scholars pay attention to invention patents and utility patents when they investigate innovation activities in China (Fang et al., 2017; Tan et al., 2020). We further study the impact of environmental taxes on different innovation types. We find that environmental taxes have a positive effect on green utility patents and fail to affect green invention patents. Finally, we also find that environmental taxes promote green innovation efficiency.

This article contributes to the literature in several ways. (1) The paper provides new and different evidence of the impact of tax policies on innovation activities. The prior literature provides extensive evidence that tax reduction can promote corporate innovation. This evidence remains valid for different capital markets, including developed countries (Atanassov & Liu, 2020; Czarnitzki et al., 2011; Li et al., 2021) and developing countries (Crespi et al., 2016; Howell, 2016; Ivus et al., 2021; Shao & Xiao, 2019), and different tax policies, such as R&D tax credits (Czarnitzki et al., 2011; Ivus et al., 2021), corporate income taxes (Atanassov & Liu, 2020; Shao & Xiao, 2019), and value-added taxes (Howell, 2016). However, using the Chinese Environmental Protection Tax Law as a quasi-natural experiment, we find that increasing taxes promotes corporate green innovation. The new and different evidence in this paper suggests that different tax policies targeting specific economic or social issues have different effects on corporate innovation activities, and the institutional backgrounds in which firms operate also play an important role in the impact of tax policies.

- (2) The paper adds academic evidence on the economic effect of the Chinese Environmental Protection Tax Law. Some papers have examined the impact of tax policies, such as firm performance (He et al., 2020; Tu et al., 2020) and air pollution (Han & Li, 2020). This paper examines the impact of the new law on corporate green innovation, which deepens our understanding of the impact of the environmental tax policy.
- (3) This paper enriches the literature on the role of environmental taxes in environmental protection. Previous studies provide tremendous evidence that environmental taxes help to reduce carbon emissions and achieve a green economy (Shahzad, 2020; Khurshid & Deng, 2021; Khurshid et al., 2022; Khurshid et al., 2022; Wang et al., 2022; Li et al., 2023; Khurshid et al., 2023b, 2023a). Given that green innovation can alleviate carbon emissions (Wang et al., 2022), the findings of this paper provide mechanistic explanations for the role of environmental taxes in promoting green development.

The rest of this paper is organized as follows. We provide the background of the Chinese Environmental Protection Tax Law in [Section 2](#), review the related literature and develop hypotheses in [Section 3](#), discuss our sample, variables, and model in [Section 4](#), and report the empirical results in [Section 5](#). In [Section 6](#), we conclude the paper and provide policy implications and further research.

2. Background of the Chinese Environmental Protection Tax Law

After the economic reform in the late 1970s, China experienced rapid growth and created an economic miracle. Due to the previous rude economic model, environmental issues accompanied economic development. The government started charging a fee for pollution in 1982, which was called the pollutant discharge policy. However, economic development was the top priority (Zhang et al., 2016). The policy had relatively low fees for pollution charges and did not distinguish between different pollutants (He et al., 2020). In 2003, China formalized a pollution charge policy, namely, the Regulations on Collection and Use of Pollution Discharge Fee, which distinguished different pollutants and increased fees for the charge. However, the policy received less success because of the lack of a legal basis for the environmental and primary goals of the economic development of local governments. Environmental issues are becoming increasingly serious with economic development. According to The Global Burden of Diseases 2010, air pollution annually causes approximately 1.2 million premature and 25 million disability-adjusted life-years in China.

Environmental issues have received increasing attention from the Chinese. People have asked the government to tackle environmental issues. After the Eighteenth National Congress of the Communist Party of China in 2012, President Xi was elected president. China's environmental governance reached a new milestone. President Xi repeatedly strengthened the importance of environmental protection and declared that green mountains and green waters are gold and silver. China began to develop a more perfect legal system. In 2014, The Ministry of Environmental Protection, together with the Ministry of Finance and the State Administration, declared that they had drafted The Chinese Environmental Protection Tax Law. In 2015, the Legislative Affairs Office of the State Council issued the draft and sought the opinions of all stakeholders of the society. The Chinese Environmental Protection Tax Law was passed at the 25th meeting of the Standing Committee of the 12th National People's Congress in 2016 and came into effect on 1 January 2018. The law defines the legal status of the pollutant discharge fee from administrative fees to taxes.

The law consists of five chapters and 28 articles. Article 1 of the law declares that the law is formulated for the purpose of protecting and improving the environment, reducing the emission of pollutants and promoting the construction of ecological civilization. Article 3 of the law mandates that air pollutants, water pollutants, solid waste, and noise are the items taxed. More importantly, article 6 of the law gives detailed information on tax items and the price of the environmental protection tax. In Chapter 4, the law provides detailed and strict regulations for the implementation of environmental taxes. For example, article 23 of the law points out that taxpayers or tax authorities are responsible for taxing. In summary, the law provides a legal safeguard for environmental governance and has significance (He et al., 2020).

Against the background that many countries are implementing the 2030 Agenda for Sustainable Development, China's government enacted the Environmental Protection Tax Law in 2018 to achieve sustainable development and reduce the adverse impact of human economic activities on the environment. Green innovation is the most important technological way to reduce environmental issues. Therefore, it is important to estimate whether the environmental tax law affect corporate green innovation in a timely manner.

3. Literature review and hypothesis development

3.1. Literature review

Taxes are one of the important policy tools that affect corporate innovation. The literature focuses on the relation between tax policy and corporate innovation (Hall, 2021). In general, the tax policies affecting innovations can be divided into two types, namely, research and development (R&D) tax credits and other tax policies. R&D tax credits involve tax grants for R&D expenditure and directly impact innovation input. Many scholars find that R&D tax incentives have a positive effect on corporate innovation (Castellacci & Lie, 2015; Czarnitzki et al., 2011; Ivus et al., 2021; Tian et al., 2020) and that firm characteristics, such as firm size (Chen & Yang, 2019) and life cycle (Chiang et al., 2012), affect the positive association between R&D tax incentives and corporate innovation. Other tax policies, such as corporate income tax and value-added tax, affect innovation activities by changing mainly corporate financial constraints. The extant literature suggests that tax reduction can stimulate innovation input and innovation outputs (Atanassov & Liu, 2020; Crespi et al., 2016; Howell, 2016; Shao & Xiao, 2019; Wang & Kesan, 2022; Zheng & Zhang, 2021). In contrast, increasing taxes has a negative effect on corporate innovation activities. For example, Atanassov and Liu (2020) document that corporate income tax cuts can promote innovation; in contrast, increasing taxes has a negative effect on innovation. Li et al. (2021) find that a tax avoidance crackdown leads to a significant decrease in innovation outputs. In summary, prior studies seem to provide a solid concept that tax reduction policies are conducive to innovation activities. However, Karydas and Zhang (2019) develop an endogenous growth model and point out that environmental taxes may promote economic growth by inducing corporate innovation under conditions: (1) labors can move between R&D sector and manufacturing; (2) the elasticity of substitution in manufacturing between energy and scarce factors should be lower than unity. Furthermore, using survey data, Stojcic (2021) finds that environmental taxes promote green innovation. The prior literature fails to reach an agreement on the impact of tax policies on corporate innovation activities.

Environmental tax has been regarded as an important tool to address environmental problems (Khurshid & Deng, 2021; Khurshid et al., 2022, 2023; Li et al., 2023; Shahzad, 2020). The Chinese government implemented the Environment Protection Tax Law in 2018, which was the first environmental tax policy. Some papers have examined the impact of tax policies. For example, using the event study method, He et al. (2020) document that the new law increases environmental costs and has a negative effect on firm performance. Han and Li (2020) use a Bayesian space-time model to test the impact of the new law on air pollution at

the provincial level in 2018 and find that the new law helps to improve air quality. Tu et al. (2020) find that a significant negative reaction is related to the new law. However, we know little about how the law affects corporate innovation.

Through a literature review, we find that there are two research gaps. First, the findings on the relationship between tax policy and corporate innovation are mixed. To ensure the impact of tax policy on corporate innovation activities, we need to provide more evidence. In addition, we fail to know how the Chinese Environmental Protection Tax Law affects corporate green innovation. Therefore, this paper examines the impact of the Chinese Environmental Protection Tax Law on corporate green innovation.

3.2. Hypothesis development

There are two opposing theoretical views about the association between environmental taxes and corporate green innovation. The first view argues that environmental taxes have a negative impact on corporate green innovation. Unlike routine investment tasks that follow conventional technology and generate quick returns, innovation is a long-term and risky process that produces intangible assets (Holmstrom, 1989). In addition, the inventor has better information about the likelihood of the nature and the likelihood of success of the contemplated innovation projects than outside potential investors (Hall & Lerner, 2010). These characteristics of innovation activities make it difficult for firms to finance innovation, and financial constraints are a key obstacle to innovation (Gorodnichenko & Schnitzer, 2013). It is inevitable for firms to cause environmental issues in operation. Compared to that of developed countries, China's economy is unsustainable, with high energy consumption, high production input, high pollution emissions, and low economic efficiency (Li & Du, 2021), suggesting that firm operation may have a greater adverse effect on the environment. After the enactment of the Chinese Environmental Protection Tax Law, firms need to pay taxes for their environmental issues. This means that environmental taxes will increase corporate burden and strengthen financial constraints, which dampen corporate green innovation (Atanassov & Liu, 2020; Howell, 2016; Hu et al., 2021; Wang & Kesan, 2022).

However, according to the Porter hypothesis (Porter & van der Linde, 1995), a stringent environment regulation may offset regulation costs and promote innovation outputs. Against the specific background of China, environmental regulations may have a larger effect on corporate innovation behaviors and lead to innovation benefits over regulation costs. Environmental taxes may have a positive effect on corporate green innovation. Although China moved from a central planned economy to a market-oriented social economic system in the late 1970s, the government still has a significant impact on firm operations (Jiang & Kim, 2020). For example, the China Securities Regulatory Commission, which is a government department and the main securities regulator in China, has hindered or restricted firms' ability to initiate public offerings and conduct seasoned equity offerings. The bank sector, the dominant source of corporate financing in China, is controlled by state-owned banks (Chong et al., 2013; Jiang & Kim, 2020). In addition to satisfying consumer requirements (Safaei et al., 2022), having a close relationship with the government helps firms obtain more resources and opportunities than firms without connections (Kim et al., 2018). One of the most important ways to build a close relationship with the government is to cater to government policies. In

recent years, the Chinese government has realized that unsustainable economic growth has been detrimental to the environment, and China needs to transition from unsustainable development to sustainable development. President Xi has strengthened the importance of environmental protection and achieved sustainable development on many occasions and pointed out that green mountains and green waters are gold and silver. In addition, the government issued many policies to achieve sustainable development, such as the Green Credit Guides in 2012, the Air Pollution Prevention and Control Action Plan in 2013, the New Environmental Protection Law in 2015, and the Chinese Environmental Protection Tax Law in 2018. These policies clearly convey the commitment that the Chinese government wants to achieve sustainable development. In this context, although the Chinese Environmental Protection Tax Law charges taxes for firms' environmental issues, firms may have a stronger incentive to engage in green innovation to cater to government governance policy.

Based on the above analysis, we propose the following hypothesis.

Hypothesis 1: The environmental protection tax reduces corporate innovation outputs.

Hypothesis 2: The environmental protection tax promotes corporate innovation outputs.

4. Sample, variables, and empirical method

4.1. Sample

To construct our sample, we start with all Chinese A share listed companies during the 2015–2019 period. Please note that the sample period is from 2016 to 2019 for green innovation and from 2015 to 2019 for the control variables. The firm financial data are collected from the China Securities Market and Accounting Research (CSMAR) database. The green patent data are collected from the Chinese Research Data Service (CNRDS) database.¹ Then, we exclude financial service firms and firm-year observations with missing information for the control variables. Our final sample includes 10,526 firm-year observations representing 3137 firms. To mitigate the effect of outliers, we also winsorize all continuous variables at the 1% and 99% levels.

4.2. Measuring corporate green innovation

Patents are the most common indicator used to measure innovation (Amore & Bannedsen, 2016; Atanasov & Liu, 2020; Fang et al., 2017; Hu et al., 2021; Kong et al., 2020), as patenting is an important means by which firms can protect their technological inventions (Chang et al., 2019). Following Hu et al. (2021), we use the number of green patents that were applied for during each firm year. According to the patent application file, the Chinese State Intellectual Property Office (CSIPO) determines the type of a patent, namely, invention patent, utility model patent, or

¹We use the data of green patents provided by the CNRDS database in 2020 because the database changes the statistic caliber in the latest data.

design patent. Scholars usually only include invention patents and utility model patents when investigating innovation activities in China, as these patents represent significant technological improvements (Fang et al., 2017; Kong et al., 2020; Tan et al., 2020). In this paper, we only include green invention patents and green utility model patents when we count the number of firm green patents. In addition, the patent application year is closer to the time of actual innovation than the grant year (Tian & Wang, 2014). Finally, due to the right skewness of the number of green patents, following Chang et al. (2019) and Kong et al. (2020), we adopt the natural logarithm of one plus the number of green invention patent applications and green utility model patent applications to measure corporate green innovation (Patent).²

4.3. Empirical model

To examine whether the Chinese Environmental Protection Tax affects corporate green innovation, we use a generalized difference-in-difference method. Specifically, we investigate the difference in green innovation output in firms that are more affected before and after the environmental tax law (“Treatment” group) compared to the same difference for firms that are less affected (“control” group).³ Therefore, to use the method, we need to divide firms into two groups, namely, the treatment group and the control group. Following Tu et al. (2020), we define a firm as the treatment group when the firm belongs to heavily polluting industries. Although government environmental regulations affect all firms, firms in heavily polluting industries face more stress from government regulations. The Ministry of Environmental Protection of China issued the Guidelines for the Disclosure of Environmental Information for Listed Companies in 2010 that defined which industries are heavily polluting.⁴ We used the guide to identify the treatment group. In addition, following Chang et al. (2019), we lag one period for all control variables because innovation needs time to develop. The following equation describes the main regression model:

$$Patent_{i,t} = \beta_0 + \beta_1 Treat_i \times Post_t + \gamma' Control_{i,t-1} + \mu_i + u_t + \varepsilon_{i,t} \quad (1)$$

where i denotes the individual firm and t denotes the year. $Treat$ is an indicator variable that equals 1 when a firm belongs to the treatment group and 0 otherwise. $Post$ is also an indicator that assumes a value of 1 to denote the post-2018 period and 0 to denote the pre-2018 period. The control variables (Controls) are the potential factors that have been shown in the literature to predict corporate innovation (Chang et al., 2019; Chen et al., 2021; Kong et al., 2020; Tan et al., 2020; Wu & Dong, 2021). We include R&D expenses scaled by total assets to control innovation input (R&D). We use the natural logarithm of the book value of assets to control the effect of firm size (Size) and use net tangi assets divided by total assets to account for capital intensity (Tangi). We capture the natural

²We design the observations without patent information as zero.

³This method is widely used to estimate the effect of policy shocks (see Kong et al., 2020; Su et al., 2022; Xu et al., 2021).

⁴Specifically, according to the Guideline for the Industry Classification of Listed Companies issued by the China Securities Regulatory Commission in 2012, listed firms with the following industry codes are defined as the treatment group (B06, B07, B08, B09, B10, B11, C14, C15, C16, C17, C18, C19, C22, C25, C26, C27, C28, C29, C30, C31, C32, and C33).

Table 1. Variable definitions.

Variables	Definition
Patent	The logarithm value of one plus the total number of green invention patent applications and green utility patent applications.
Treat	An indicator variable that equals 1 when a firm belongs to the treatment group and 0 otherwise.
Post	An indicator that assumes a value of 1 to denote the post-2018 period and 0 to denote the pre-2018 period.
RD	R&D expenditure scaled by total assets.
Size	The natural logarithm of total assets.
Lev	Total debt divided by total assets.
Tangi	The natural logarithm of the net tangible asset divided by total assets.
Cash	Operating cash flow divided by total assets.
ROA	Net profit divided by total assets.
Indep	The number of independent directors divided by the number of directors.
Age	The natural logarithm of firm age.
Duality	A dummy variable that equals 1 when CEO is the same as chairperson, and 0 otherwise.

logarithm of firm age to control the impact of a firm's life cycle (Age). Return on assets (ROA) is used to capture operating profitability. We use total debt divided by total assets (Lev) and operating cash scaled by total assets (Cash) to control the effect of capital structure. In addition, we control for the effect of corporate governance on innovation. Specifically, we use the ratio of independent directors (Indep) and CEO duality (Duality). Finally, we also include firm fixed effects (μ_i) to control unobservable time-invariant firm-specific characteristics and year fixed effects (v_t) to control time trends.⁵ All variables are defined in Table 1.

5. Empirical results

5.1. Descriptive statistics

Table 2 reports the summary statistics on the variables used in our analysis. As shown in Table 2, the mean value and median value of patents are 1.0118 and 0.6931, respectively,

Table 2. Descriptive statistics.

Variable	N	Mean	Std	Min	Median	Max
Patent	10526	1.0118	1.2367	0.0000	0.6931	4.9488
Treat	10526	0.3430	0.4747	0.0000	0.0000	1.0000
Post	10526	0.5558	0.4969	0.0000	1.0000	1.0000
RD	10526	0.0217	0.0185	0.0001	0.0185	0.0998
Size	10526	22.1425	1.2513	19.9692	21.9861	26.0591
Lev	10526	0.4031	0.1998	0.0596	0.3872	0.9132
Cash	10526	0.0439	0.0659	-0.1490	0.0430	0.2283
ROA	10526	0.0377	0.0653	-0.2980	0.0389	0.1873
Tangi	10526	0.2023	0.1460	0.0033	0.1719	0.6577
Age	10526	1.9583	0.9383	0.0000	2.0794	3.2581
Indep	10526	0.3765	0.0536	0.3333	0.3636	0.5714
Duality	10526	0.3086	0.4619	0.0000	0.0000	1.0000

The table presents descriptive statistics for the corporate green innovation measure, treatment group measure, and control variables.

⁵We do not include the variables, Treat and Post, because we control these variables that are absorbed by the firm and year fixed effects (Kong et al., 2020; Su et al., 2022; Xu et al., 2021)

indicating that there are large differences in green innovation outputs among firms. The findings are similar to those of Hao and He (2022). The mean value of Treat is 0.3430, suggesting that approximately 34% of the observations belong to the treatment group. In addition, the mean value of RD is 0.0217, which is close to the finding of Kong et al. (2020). Finally, we find that CEO duality accounts for 30.86%.

5.2. Main regression

Table 3 represents the result of Equation (1). In Column 1, we only regress Patent on Treat×Post, and the coefficient of Treat×Post is positive and significant at the 1% statistical level, indicating that environmental taxes promote corporate green innovation. In Column 2, we control R&D investment (RD), firm size (Size), capital structure (Lev and Cash), and return on assets (ROA), and the coefficient of Treat×Post is positively significant. In Column 3, we add all control variables, and the coefficient of Treat×Post is positive and significant at the 5% statistical level, suggesting that environmental taxes have a positive effect on corporate green innovation. This finding supports Hypothesis 2 and is consistent with the theoretical view of Karydas and Zhang (2019) that a higher environmental tax may stimulate corporate technological innovation. This means that the effect of environmental taxes on innovation is different from that of other tax policies.

Table 3. Main results.

	(1) Patent	(2) Patent	(3) Patent
Treat×Post	0.0786*** (0.0284)	0.0686** (0.0282)	0.0686** (0.0281)
RD		2.8384** (1.2759)	2.7220** (1.2741)
Size		0.0922*** (0.0342)	0.0623* (0.0355)
Lev		−0.0424 (0.1077)	−0.0855 (0.1090)
Cash		−0.162 (0.1500)	−0.147 (0.1511)
ROA		0.6518*** (0.1785)	0.6492*** (0.1795)
Tangi			−0.214 (0.1610)
Age			0.1817*** (0.0377)
Indep			0.148 (0.2720)
Duality			0.0354 (0.0315)
Constant	0.9748*** (0.0126)	−1.107 (0.7475)	−0.764 (0.7888)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	10526	10526	10526
R ²	0.0990	0.104	0.107

The table reports the results of the impact of environmental taxes on corporate green innovation. The standard errors clustered at the firm level are reported in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

In terms of control variables, we find that more R&D investment can promote corporate green innovation, and larger firms have more green patents, which is consistent with the findings of Chang et al. (2019). In addition, the coefficient of ROA is significantly positive, indicating that firms with better profitability usually have more green innovation. Finally, we fail to find that independent directors have a significant effect on green innovation, which is consistent with the fact that firms usually employ independent directors to meet regulatory requirements and that independent directors do not play a vital role in corporate governance (Jiang & Kim, 2015).

5.3. Sensitivity tests

In this subsection, we run several sensitivity tests. First, to better measure innovation outputs, scholars also use patent citations to measure scientific value or patent quality (Chang et al., 2019; Tan et al., 2020). Therefore, we replace the measure of corporate green innovation in Column 1 of Table 4. Specifically, we use the natural logarithm of the total number of green invention patent citations and green utility model citations to measure corporate green innovation (Patent1). As shown in Column 1 of Panel A in

Table 4. Sensitivity tests.

	(1) Cite	(2) Patent	(3) Patent	(4) Patent
Treat×Post	0.2559*** (0.0278)	0.0915** (0.0415)	0.0675** (0.0282)	
RD	-0.522 (1.2444)	3.7707** (1.6977)	2.5941** (1.2743)	2.7838** (1.2759)
Size	-0.1279*** (0.0369)	0.1274** (0.0517)	0.0659* (0.0358)	0.0597* (0.0357)
Lev	0.112 (0.1043)	-0.3023* (0.1785)	-0.0823 (0.1091)	-0.0819 (0.1091)
Cash	0.0372 (0.1355)	-0.0360 (0.2209)	-0.136 (0.1523)	-0.148 (0.1510)
ROA	0.149 (0.1396)	0.7665*** (0.2676)	0.6540*** (0.1817)	0.6285*** (0.1797)
Tangi	-0.4581*** (0.1514)	-0.0476 (0.2820)	-0.202 (0.1628)	-0.214 (0.1608)
Age	0.2945*** (0.0350)	0.1114* (0.0632)	0.1838*** (0.0377)	0.1834*** (0.0376)
Indep	-0.0487 (0.2683)	-0.0518 (0.3859)	0.177 (0.2739)	0.162 (0.2722)
Duality	0.0471 (0.0288)	0.0239 (0.0450)	0.0372 (0.0315)	0.0365 (0.0316)
AQI			0.2997** (0.1292)	
Treat×Year2016				0.0103 (0.0386)
Treat×Year2017				-0.0327 (0.0339)
Treat×Year2019				0.1136*** (0.0332)
Constant	2.9896*** (0.8148)	-1.138 (1.1595)	-2.1638** (0.9654)	-0.722 (0.7916)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N	10526	5593	10470	10526
R ²	0.183	0.178	0.108	0.108

The table reports the results of sensitivity tests. The standard errors clustered at the firm level are reported in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 4, the coefficient of $\text{Treat} \times \text{Post}$ is positive and significant at the 1% statistical level, suggesting that environmental taxes promote green innovation.

Second, in the main regression, we set the counts to 0 when firms have no green patent information in the CNRDS database, which may cause bias because some firms do not apply patents for their technology. Following Chang et al. (2019), we exclude observations that have zero green innovation and use Equation (1) to examine the impact of environmental taxes on corporate green innovation. As shown in Column 2 of Panel A in Table 4, the results mean that environmental taxes have a positive effect on corporate green innovation.

In addition, we further examine the impact of air quality. Air quality is an important variable that may simultaneously affect green innovation and the implementation of the Environmental Protection Tax Law. On the one hand, Wang et al. (2022) find that heavy pollution makes firms tend to develop more green innovation. On the other hand, air pollution attracts more attention from residents who urge the government to take action to improve environmental protection, such as legislation and environmental taxes. Therefore, the missing variables that measure air quality may drive the relationship between environmental taxes and corporate green innovation. In Column 3 of Panel A in Table 4, we control for the effect of air quality. Specifically, we use the natural logarithm of the air quality index to measure air quality (AQI). As shown in Column 3, the coefficient of $\text{Treat} \times \text{Post}$ is positive and significant at the 5% statistical level, suggesting that the findings of this paper remain valid.

Finally, the parallel assumption should be satisfied when we use the DID method, meaning that the numbers of patents trend closely in parallel for the two groups before the Chinese Environmental Protection Tax Law. Following Xu et al. (2020), we regress Equation (1) with dynamic dummies to formally test the assumption. Specifically, we develop four dummy variables (Year2016, Year2017, Year2018, and Year2019). Then, we generate the interaction between these dummy variables and Treat ($\text{Treat} \times \text{Year2016}$, $\text{Treat} \times \text{Year2017}$, $\text{Treat} \times \text{Year2018}$, and $\text{Treat} \times \text{Year2019}$). Then, we use these interactions to replace $\text{Treat} \times \text{Post}$ in Equation (1). The regression coefficients of $\text{Treat} \times \text{Year2016}$ and $\text{Treat} \times \text{Year2017}$ should be insignificant when the parallel assumption is satisfied.⁶ In Column 4 of Table 4, we find that the parallel trend assumption is satisfied.

5.4. Mechanism tests

The analysis in the previous sections identifies a significantly positive association between environmental tax and corporate green innovation. In this subsection, we explore the economic mechanism through which environmental taxes affect corporate green innovation. Prior studies find that increasing taxes have a negative effect on innovation activities. However, against this specific background, although environmental taxes increase the corporate tax burden, we contend that to obtain resources and potential opportunities, firms have an incentive to cater to the determination of government environmental governance by green innovation to develop a close relationship with the government. Different ownership structures have different abilities to access resources and potential opportunities in China, which provides a chance to investigate

⁶The interaction term of $\text{Treat} \times \text{Year2018}$ is excluded from the regression because we use the interaction term as the benchmark.

the economic mechanism through which environmental taxes affect corporate green innovation. In China, the government plays an important role in resource allocation. SOEs are controlled by the government and have a natural intimate relationship with the government, which gives SOEs more advantages over non-SOEs (Hu et al., 2021). For example, the Chinese bank sector controlled by state-owned banks prefers lending to SOEs regardless of their profitability, leaving non-SOE credit constraints (Ayyagari et al., 2010). In addition to banks, other financial institutions also prefer to provide funds for SOEs, such as mutual funds (Yang et al., 2014). Therefore, to obtain the resources and opportunities that determine firm operation, non-SOEs have more incentive to develop green innovation to cater to government environmental governance compared to SOEs.

We divide firms into two subsamples according to corporate ownership, namely, SOEs and non-SOEs. Then, we use Equation (1) to examine the impact of environmental taxes on corporate green innovation. As shown in Table 5, the coefficient of $Treat \times Post$ is positive and significant for non-SOEs, supporting the view that although environmental taxes increase the corporate tax burden, firms are willing to engage in green innovation to cater to government environmental governance.

5.5. Cross-sectional heterogeneity in results

5.5.1. The effect of product market competition

Production market competition may affect the relationship between environmental taxes and corporate green innovation. Firms can set higher prices and receive higher profits in

Table 5. Mechanism tests.

	SOEs Patent	non-SOEs Patent
Treat×Post	0.0323 (0.0525)	0.0812** (0.0337)
RD	3.038 (2.2863)	2.7219* (1.5339)
Size	0.1238** (0.0508)	0.0580 (0.0464)
Lev	−0.234 (0.2129)	−0.0379 (0.1274)
Cash	−0.121 (0.2974)	−0.152 (0.1797)
ROA	0.291 (0.3213)	0.6720*** (0.2173)
Tangi	0.158 (0.3197)	−0.4514** (0.1778)
Age	0.0870 (0.1299)	0.2236*** (0.0427)
Indep	−0.198 (0.4339)	0.311 (0.3513)
Duality	0.0124 (0.0681)	0.0442 (0.0359)
constant	−1.642 (1.2122)	−0.835 (1.0194)
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
N	3055	7463
R ²	0.129	0.0998

The table reports the results of the mechanism tests. The standard errors clustered at the firm level are reported in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

a highly concentrated market (Bian, 1951), which makes these firms have more resources and reduces their dependence on external resources. In addition, firms in a concentrated market can transfer taxes to consumers, which lowers the impact of government policy on firms' operations. In contrast, in a fierce product market, to gain a competitive advantage, firms have more incentive to cater to government environmental governance. Therefore, we expect that product market competition affects the relationship between environmental taxes and corporate green innovation. We use the Herfindahl index (HHI) to measure product market competition.⁷ Then, we divide samples into two subsamples by the median value of the index. As shown in Column 1 and Column 2 of Table 6, environmental tax has a significant positive effect on corporate green innovation in fierce market product competition.

5.5.2. *The effect of financial constraints*

Financial constraints are a key factor by which tax grants can promote corporate innovations because tax grants alleviate financial constraints, making firms invest more in innovation (Gorodnichenko & Schnitzer, 2013; Shao & Xiao, 2019; Wang & Kesan, 2022). However, the Chinese financial system is controlled by state-owned banks, and the government can affect corporate green innovation through bank credit (Hu et al., 2021). For example, to develop a sustainable economy, the Chinese government issued the Green Credit Guidelines in 2012, which asked banks to provide preferred credit to firms engaging in green operations. Therefore, firms facing strict financial constraints may develop more green innovation to cater to government environmental taxes. Following Chang et al. (2019), we use firm size to classify whether firms face larger financial constraints. We partition the sample according to the median value of firm size. Larger firms have fewer financial constraints than smaller firms. We conjecture that the association between environmental taxes and corporate green innovation is more prominent for firms with more strict financial constraints. As shown in Columns 3 and 4 of Table 6, firms with more strict financial constraints engage in more green innovation.

5.5.3. *The effect of marketization*

In terms of marketization, there are tremendous differences across China. Eastern regions have higher marketization (Fan et al., 2011; Tan et al., 2020), and some cities, such as Shanghai, Guangzhou, and Shenzhen, have a similar degree of marketization as developed countries.⁸ Higher marketization means that firms have more chances to access external resources and reduce their dependence on government. In addition, the government intervenes less in firm operations in regions with higher marketization (Fang et al., 2017). Therefore, firms located in areas with higher marketization have less incentive to engage in green innovation to cater to government environmental governance. Following Tan et al. (2020), we divide our sample into two subsamples, namely, firms located in eastern regions and firms located in other regions. We argue that the relationship between environmental taxes and corporate green innovation is more prominent for firms located in the low marketization regions, namely, non-eastern

⁷We classify the manufacturing industry into more detailed industry categories using the 3 codes when we measure production market competition.

⁸Eastern regions include Beijing, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan provinces.

Table 6. Cross-sectional analysis.

	(1) High HHI Patent	(2) Low HHI Patent	(3) Larger firms Patent	(4) Smaller firms Patent	(5) High marketization Patent	(6) Low marketization Patent
TreatxPost	0.1179*** (0.0415)	0.0423 (0.0423)	0.0484 (0.0423)	0.0765* (0.0397)	0.0436 (0.0347)	0.1163** (0.0481)
RD	1.007 (1.7707)	4.9025** (1.9082)	7.6403*** (2.2750)	-0.525 (1.5072)	2.9448** (1.4805)	2.217 (2.5560)
Size	0.0928* (0.0555)	0.0654 (0.0458)	0.0879 (0.0632)	0.0598 (0.0610)	0.0914* (0.0471)	0.0128 (0.0510)
Lev	-0.0535 (0.1689)	-0.0757 (0.1485)	-0.0188 (0.2105)	-0.0983 (0.1292)	-0.194 (0.1333)	0.158 (0.1867)
Cash	-0.0880 (0.2225)	-0.181 (0.2107)	0.0245 (0.2593)	-0.224 (0.1852)	-0.0201 (0.1872)	-0.402 (0.2615)
ROA	0.5078** (0.2577)	0.6863*** (0.2476)	1.0312*** (0.3303)	0.357 (0.2177)	0.3699* (0.2148)	1.1406*** (0.3125)
Tangi	0.0724 (0.2516)	-0.312 (0.2053)	-0.321 (0.3125)	-0.0619 (0.1981)	-0.339 (0.2163)	-0.0143 (0.2370)
Age	0.1991*** (0.0542)	0.1525*** (0.0544)	-0.0160 (0.1041)	0.1643*** (0.0480)	0.2020*** (0.0439)	0.1259* (0.0764)
Indep	0.7875* (0.4330)	-0.460 (0.3577)	-0.493 (0.3938)	0.7312* (0.3758)	-0.0104 (0.3442)	0.550 (0.4351)
Duality	0.0163 (0.0461)	0.0630 (0.0448)	-0.00320 (0.0515)	0.0635 (0.0429)	0.0336 (0.0384)	0.0526 (0.0552)
Constant	-1.662 (1.2291)	-0.649 (1.0264)	-0.503 (1.4371)	-1.120 (1.2944)	-1.269 (1.0320)	0.0711 (1.1803)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5212	5314	5263	5263	7129	3397
R ²	0.120	0.102	0.152	0.0760	0.109	0.106

The table reports the results of cross-sectional heterogeneity. The standard errors clustered at the firm level are reported in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

regions. As shown in Columns 5 and 6 of Table 6, we find that environmental tax has a positive and significant effect on corporate green innovation in the low marketization regions.

5.6. Additional analysis

In this section, we run two additional analyses. First, we examine whether environmental taxes improve corporate green innovation efficiency. Following Chang et al. (2019), we use the natural logarithm of one plus the total green invention patents and green utility model patents over R&D expenditures to measure corporate green innovation efficiency (Efficiency), which captures a firm's ability to generate green patents per R&D expenditure. In Column 1 of Table 7, we find that environmental taxes improve corporate green innovation efficiency.

Second, we examine the impact of environmental taxes on different types of green innovation, namely, green invention innovations and green utility model innovations. We use the natural logarithm of one plus the number of green invention patent applications to measure green invention innovations (Invention) and the natural logarithm of one plus the number of green utility model patent applications to measure green utility model innovations (Utility). According to Chinese patent law, invention patents have the highest number of novel technologies and are granted a new technological solution relating to a process, a product, or an improvement. Utility model patents have fewer

Table 7. Additional analysis.

	(1) Efficiency	(2) Invention	(3) Utility
Treat×Post	0.0098** (0.0044)	0.0396 (0.0249)	0.1061*** (0.0236)
RD	0.0107 (0.1406)	2.3110* (1.1832)	0.615 (0.9866)
Size	−0.0227*** (0.0053)	0.0926*** (0.0325)	−0.0277 (0.0295)
Lev	−0.0104 (0.0180)	−0.0785 (0.0976)	−0.0211 (0.0922)
Cash	−0.0795*** (0.0263)	−0.00440 (0.1319)	−0.2359* (0.1325)
ROA	0.0545* (0.0326)	0.6111*** (0.1594)	0.3113** (0.1531)
Tangi	−0.0228 (0.0300)	−0.00160 (0.1464)	−0.3512*** (0.1320)
Age	0.00830 (0.0055)	0.0855*** (0.0328)	0.2528*** (0.0315)
Indep	−0.0706 (0.0441)	0.0423 (0.2402)	0.194 (0.2475)
Duality	−0.0007 (0.0043)	0.0383 (0.0276)	0.0019 (0.0263)
Constant	0.5866*** (0.1205)	−1.5743** (0.7208)	0.835 (0.6602)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	10334	10526	10526
R ²	0.0540	0.0358	0.183

The table shows the results of additional analysis. The standard errors clustered at the firm level are reported in parentheses. The symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

novel technologies and are granted for new and practical technical solutions relating to the shape and/or structure of a product. In Columns 2 and 3 of [Table 7](#), we find that environmental taxes fail to affect green invention innovations but promote green utility model innovations. This may be because green utility model innovations need fewer resources to develop than green invention innovations, which means that enterprises can cater to the demand of governments for green patents in a short time with few resources.

6. Discussion

6.1. Conclusion

In this paper, we examine how environmental taxes affect corporate green innovation. To address potential endogeneity issues, we explore the enactment of the Chinese Environmental Protection Tax Law in 2018 as a quasinatural experiment. (1) Using the DID method, we document that environmental taxes promote corporate green innovation, which is different from the findings of prior studies that argue that increasing the tax burden hampers innovation activities. (2) The finding is valid for replacing the measure of green innovation, excluding observations with zero green innovation output, controlling the impact on air quality, and testing the parallel trend assumption of the DID method. (3) Mechanism tests find that firms engage in green innovation to cater to government environmental governance. (4) Cross-sectional heterogeneity analyses find that the association between environmental tax and corporate green innovation is more prominent for firms within intense product market competition, firms with strict financial constraints, and firms located in higher marketization regions. (5) Addition analyses find that environmental tax has a significant effect on corporate green innovation efficiency and green utility model innovations but fails to affect green invention innovations.

6.2. Policy implications

The evidence provided in this paper has important policy implications for policy-makers who want to stimulate green innovation. To stimulate green innovation and achieve sustainable development, the government can consider the following advice:

- (1) The government should improve the cultivation of enterprises' environmental awareness. The finding that firms engage in green innovation to cater to government environmental governance means that obtaining resources controlled by the government drives firms to develop more green innovation and that firms have less incentive to voluntarily adopt green innovation. Improving enterprises' environmental awareness can induce enterprises to actively reduce the impact of firms' operations on the environment.
- (2) Meanwhile, this paper finds that the impact of environmental taxes on green innovation is less prominent in regions with higher marketization. Firms that have more chances to access external resources fail to achieve the aim of the Environmental Protection Tax Law. To promote corporate green transformation,

the government can consider raising environmental taxes in these regions and improving the enforcement of environmental tax laws. These measures can increase the constraint of environmental taxes and make firms located in areas with lower marketization have more incentive to develop green innovation.

6.3. Limitations and further research directions

Notably, this paper provides limited mechanisms to explain how environmental taxes affect corporate green innovation. Taxes, an important policy tool, may affect corporate innovation through many channels. Further research can provide more mechanism tests to identify how environmental taxes affect corporate green innovation. In addition, patents are one of the important ways that firms protect innovation outputs. Firms also keep innovation outputs secret, which makes patent data fail to reflect total innovation outputs. Therefore, further analysis can help find a better measurement of innovation outputs.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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