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Original Research

Environmental Audit and Green Innovative Strategy of Enterprise in China

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Abstract

Environmental audit is regarded as a kind of voluntary regulation and an important tool for environmental certification. This paper aims to investigate the impact of environmental audit on innovation strategy of enterprise in the short and long term, separately. Samples and dataset are established by 437 listed companies in China and their business and environmental data from 2009 to 2020, respectively. To identify the innovation strategy accurately, the innovation strategy of enterprise is divided into technology introduction, independent innovation, and technology cooperation. Environmental audit is selected as a proxy variable of voluntary environmental regulation. The results show that environmental audit positively affects technology introduction, independent innovation, and technology cooperation. Further, the sample companies are divided into two groups according to pollution intensity, and it finds that high-pollution enterprises are more inclined to technology cooperation and technology introduction in the short term. For these enterprises, they will not continue to upgrade technology in the long term after meeting environmental requirements. For low-pollution enterprises, the positive effect of environmental audit on innovation strategy is sustained, no matter in the long or short term. Besides, low-pollution enterprises are more focused on technology introduction and technology cooperation in the long term.

Keywords: digital technology, environmental regulation, evolutionary game model, simulation analysis, sustainable green development

Introduction

Mandatory environmental regulation and market-based environmental regulation that have been implemented in China for a long time, can guide enterprises to reduce negative environmental externalities while completing production. Environmental regulation brings higher production costs to enterprises as well as higher supervision costs to the government [1]. Strict environmental regulations may affect resource allocation of enterprises, even has some impacts on green innovative strategies through crowding-out effect [2]. Many kinds of environmental regulations, such as SO_2 emission trading, carbon emission trading, emission standard of air pollution, have been designed and carried out in China. With the implementation of different types of environmental policies, it seems that increasing intensity

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of environmental management may seriously affect the development of enterprises and even cause more serious damage to the environment [3]. Besides, much research has confirmed that existing environmental policies are having less and less impact on business innovation and environmental performance [4, 5]. More and more policymakers begin to focus on more flexible environmental regulation that guide enterprises to proactively report environmental information and review their own environmental behavior. The emergence of voluntary environmental regulation has well filled the gap of current environmental management policies and guided enterprises to actively adapt production process to the environment [6]. Therefore, the environmental audit of listed companies has received more and more attention.

In the face of environmental pressure, managers usually want to reduce the impact of environment on business operations [2]. Green innovation is an effective means for enterprises to cope with environmental pressure. Previous literature indicates that environmental regulations will increase the operating costs of enterprises and interfere with the optimal allocation of resources that affect R&D expenditure and innovation ability of enterprises [7, 8]. Porter and Van der Linde think that strict and flexible environmental regulation could encourage enterprises to innovate and establish competitive advantages [9]. Tremendous literature has examined the relationship between environmental regulation and innovation [10-13]. Environmental tax [14], pollution fee [15], and emission trading [16] are selected as a proxy variable of market-based environmental regulation, and environmental standard is seen as a proxy variable of mandatory environmental regulation [17]. Environmental audit is an important part of ISO14001 that accepts by lots of Chinese enterprises. Environmental audit is an agreement, commitment or plan proposed by the industry association, enterprise or other subject, and enterprises have the rights to decide to participate in it or not [18]. However, confused conclusions still exist that there is no clear conclusion on the impact of voluntary environmental regulation on innovation. Some research confirms Porter and Van der Linde, and some literature support traditional view. Moreover, we also find that there is little research on voluntary environmental regulation [19, 20]. This study is motivated by the above situation and attempts to explain the above situation from a technical perspective.

This paper examines the impact of voluntary environmental regulation on firm's green innovation strategy, and environmental audit is selected as a proxy variable of voluntary environmental regulation. The green innovation strategy of enterprise is divided into technology introduction, technology cooperation and independent innovation. This study will contribute to literature in the following aspects. First, this study describes green technology innovation from three perspectives, and has a more detailed understanding of the internal green innovative strategy of enterprise technology. Second, this study uses environmental auditing, which is more flexible and softer, to test Porter's hypothesis. This provides a broader perspective on current research and possible explanation for the confused conclusions. It also provides additional attention to voluntary environmental regulation in the literature. Third, this study provides a new focus for research on Porter's hypothesis. The research should focus more on the green technology strategy of the firm rather than whether the firm is innovative. Green innovation is only one part of a company's green strategy, and enterprises have more green strategies to meet environmental requirements.

The paper is organized as follows. The theory and literature review are in Section 2. Sample, data, and variables are presented in Section 3. Section 4 provides empirical results, discussion, robustness test and heterogeneity analysis. Section 5 presents the conclusions.

Theory and Literature Review

Theoretical Foundation and Mechanisms

The neo-institutional theory holds that modern organizations are becoming more and more similar not because of competitive homogeneity in the market, but institutional homogeneity subject to external institutional pressure [21]. The laws, regulations and other provisions on organizations given by the state, government and other authorities require organizations to meet the requirements in order to achieve cognitive legitimacy and moral legitimacy [22]. Environmental regulation, which is an important part of the institutional framework, is regarded as an instrument to intervene in the environmental pollution from enterprises. Environmental policies change organizations at different levels through three carriers: culture, social structure, and organizational practices. Regulative pillar monitors organizational behavior through the establishment of rules, rewards, and punishments. When enterprises are faced with environmental pressure from the government and laws, they need to satisfy the environmental legitimacy in the shortest time to avoid being punished. In economic theory, environmental regulations by government are regarded as the external cost of enterprises and have an impact on resource allocation [7]. These external costs are unproductive and cannot bring subsequent benefits to the enterprise in the future, which is known as the environmental compliance cost [23]. As a result, companies should divert funds from production or research to meet environmental legitimacy that is named the crowding-out effect of innovation investment. This crowding-out effect damages the normal process of R&D and weakens the competitive advantage of enterprises [24].

According to the resource-based theory, the resources owned by enterprises are different and have heterogeneity, which determines the difference of enterprise competitiveness and the designation of technology strategy [25]. Green innovative strategy can build a competitive advantage and improve performance of enterprise [26]. It provides accurate direction for a firm to meet external changes, national laws, and environmental policies through specific technological plans. Green innovation achieves the environmental objectives and decrease the ecological footprint in the products and the production processes [27]. Green innovative strategy is an integration of green innovation into a firm's corporate strategy. In current business environment, an enterprise often faces intense environmental pressure to drive green innovations because of stakeholders' expectations and environmental legitimacy in both the short and long term [2]. When the pressure of environmental legitimacy comes, enterprises expect technology and equipment upgrading to meet environmental standards in a short period of time. Independent technological innovation has a high degree of uncertainty and risk, which makes it impossible for enterprises to predict the future innovation performance [28]. At the same time, innovation also requires long-term and large capital investment by enterprises. However, this may not be consistent with the expectations of shareholders. Therefore, enterprises should not only focus on independent technological innovation, but also seek external technical resources to achieve their own technological improvement when they design and implement green innovation strategy in the short time.

Technology introduction and technology cooperation are effective ways to upgrade technology and meet emission standards in the short term [29]. Technology introduction can help enterprises quickly realize technology upgrading and avoid the uncertainty and risk of research and development. Moreover, Enterprises realize re-innovation by digesting and absorbing imported technologies [30]. Many studies prove that technology introduction is an effective technology strategy and has a positive impact on the innovation of enterprises [31-33]. Technology cooperation is another effective way to promote innovation. On the one hand, technical cooperation with universities or other institutions can bridge the technological gap of enterprises [34]. Technical cooperation improves the efficiency of external resources, quickly responds to the technical needs of enterprises, and realizes the technological leapfrog of enterprises in a short period of time. On the other hand, technical cooperation also enables companies to remove barriers from patents or licensing [35]. Technical cooperation allows companies to easily acquire the right to use some technology without worrying about the legal and litigation risks. Technical cooperation can also reduce the cost of innovation and optimize the allocation of innovation resources.

Literature Review

Environmental Regulation and Green Innovation

Porter and Van der Linde indicate that flexible environmental regulation may trigger firm's innovation [9]. Environmental regulations bring enterprise environmental pressure and drive them toward green production and green innovation. The benefits of innovation can compensate the cost of environmental regulation and enhance the competitive advantage of enterprises that is innovation-offset effect [36], and this relationship between environmental regulation and innovation is named as the weak Porter effect by Jaffe and Palmer [37]. Since then, many studies have attempted to reveal the relationship between environmental regulation and innovation by data from different countries or industries.

There are many studies that attempt to test and confirm Porter and Van der Linde's standpoint. Some studies begin to test the relationship between environmental regulation and R&D expenditure. Generally, R&D expenditure is consistent with corporate innovation that is the more R&D expenditure, the more innovation [38]. Chakraborty and Chatterjee focus on leather and textile industries in India, they employ environmental data and R&D expenditure of upstream firms and find a positive relationship between environmental regulation and R&D expenditure [39]. Yang, et al. study environmental regulation and R&D expenditure in the manufacturing sector of Taiwan Province from 1997 to 2003 and find that pollution control cost promotes the R&D expenditure of manufacturing sector, however, has no significant effect on the R&D expenditure of manufacturing sector [40]. Some research also uses the number of patents to examine the relationship between environmental regulation. Kesidou and Wu find that stricter pollution targets trigger a higher number and intensity of green patents [41]. Li, et al. use the number of green patent application as a proxy variable of green innovation, and confirm that stringent environmental regulation may trigger innovation [42]. However, opposite conclusions still exist. Yuan and Xiang find the crowding out effect exists in the manufacturing sector of China [3]. They regard environmental regulation as a kind of inherent productive cost. Environmental pressure means that enterprise must consider the pollution issue during the whole productive process. Enterprises have to divert some research and development funds for pollution control. Some studies also confirm that environmental regulation would crowd out innovation input and has a significant negative impact on green innovation [43, 44]. Hence, the relationship between environmental regulation and green innovation is still confused.

Environmental Regulation, Technology Introduction, and Technology Cooperation

According to the resource-based theory, innovative strategy of enterprise is based on its current resource capability. Environmental pressure will guide enterprise from current technology strategy to a new strategy for a stable dynamic equilibrium based on existing technical resources [45]. The power of environmental policy makes up the defect from market failure and guides producers to control pollution through upgrading technology. Wang finds that the intensity of environmental regulation has a threshold on green. Higher intensity of environmental regulation will encourage firms to search for external technology resource rather than independent innovation [46]. Beckstedde, et al. focus on the relationship regulatory sandboxes and energy technology innovation. Environmental regulation speeds up innovation in energy through open innovation that enterprise fall back on external resource for rapid innovation [47]. Environmental regulation can also benefit low-technology firms that environmental regulation helps these firms improve innovation level through Innovation diffusion from other enterprises [48]. Liu and Li also find that non-state-owned firms prefer external technology rather than state-own firms because that non-state-owned firms do not have sufficient innovation resources compared with state-owned enterprises [49].

Another way in which environmental regulation affects the use of external technological resources by enterprises is to affect foreign direct investment (FDI). It's a passive approach that environmental regulation has an impact on external technology using of firms. Environmental regulations prohibit external dirty technologies from entering the host country, and host country enterprises can upgrade and re-innovate technologies through introduction and absorption [50]. Dong, et al. find that domestic enterprises adopt cooperation with foreign enterprises to introduce equipment or production lines, so as to enhance their technological level and innovation ability [51]. Pan, et al. also find that environmental information disclosure, which is seen as a kind of voluntary environmental regulation, can make it easier for domestic enterprises to learn about the current technology of foreign enterprises and adjust their technology strategies [52].

Methodology

Sample and Data

Chinese listed firms in manufacturing industry are selected as research samples in this study. Compared to non-manufacturing firms, manufacturing enterprise are important support for China's economic development. Manufacturing enterprises face greater environmental pressure, especially from social supervision and attention. In addition, environmental costs and international environmental barriers make manufacturing enterprises more willing to participate in green innovation and environmental protection. Listed firms in China's manufacturing sector are selected as samples from 2009 to 2020. Those firms with missing data or ST label after 2009 are excluded. Finally, this study obtains 437 firms and 5244 observations.

In this paper, patent data is from CNIPA (China National Intellectual Property Administration) and incoPat, which is an official database for patent data statistics. Data about environmental audit is from corporate responsibility report or social responsibility report of the listed company every year. Business and accounting data come from CSMAR (China Stock Market & Accounting Research Database). Some indicators about price or value in this study are treated with a deflator index based on prices in 2009.

Variables

Independent Variable

ISO 14001 is seen as a voluntary environmental regulation that drive firms to improve environmental performance and green innovation [53]. Environmental audit, which is a positive environmental externality behavior of enterprises and an important support for environmental management certification, is an important part of ISO 14001 [54]. Here, this study employs environmental audit (*env_aud*) as an independent variable. According to the measurement method by Inoue, et al. [55], the enterprise will be assigned a value of 1 if the enterprise publishes its environmental audit report. The enterprise is given a value of 0 if it does not publish its report.

Dependent Variable

Green innovative strategy is employed as a dependent variable in this paper. According to the resource-based theory, resources heterogeneity determines the enterprise's technology strategy [25]. Li deconstructs the technology strategy into three dimensions, including technology introduction, technology cooperation and independent innovation [2]. Technology introduction (tech_intro) in this study means that enterprise obtains or purchases green technology from domestic firms or foreign firm in the technology market [56]. Technology cooperation plays an integral role in technology development. The technology cooperation process can be viewed as an adaptation of technology transfer [34]. Technology cooperation presents a positive impact on innovation [29]. Here, according to the measurement by Li [2], technology introduction (*tech_intro*) is measured by expenditures on purchasing technology and equipment, technology cooperation (*tech_co*) is measured by expenditures paid by an enterprise to a university or institute for green technology cooperation.

Independent innovation (*ind_inno*) is measured by the numbers of green patent application.

Control Variable

There are also several control variables in this paper. Long firm's age *(age)* means more technical reserves and social resources [57] as well as firm size *(size)* [58]. We use total assets as a proxy variable for firm size. State-owned enterprise *(owner)* is assigned a value of 1 and non-state-owned enterprise is 0 [59]. Higher return on assets *(roa)* means more investment in innovation [60]. Higher debt-to-assets ratio *(debt)* means enterprise has to use more earnings to pay off maturing debt, which affects R&D investment [61, 62]. An enterprise whose chairman or managing director has a political title *(title)* is given a value of 1. If decision-makers have the attribute of political connection, it will have an impact on the innovation of enterprises [63]. All variables are presented in Table 1.

Regression Model

In this section, it first establishes a regression model (1) to examine the impacts of environmental audit on technology introduction, technology cooperation, and independent innovation in a short time, respectively.

$$tech\_intro_{it} / tech\_co_{it} / ind\_inno_{it} = a_0 + a_1 env\_aud_{it} + \sum a_t X_{it} + \gamma_t + \eta_i + \varepsilon_{it} \quad (1)$$

Then, this study establishes a regression model (2) to examine the impacts of environmental audit with a one -year lag on technology introduction, technology cooperation, and independent innovation in a long time, respectively. According to production practice, environmental regulation would not only affect current innovation activity, but also has an influence on innovation in the future.

$$tech\_intro_{it} / tech\_co_{it} / ind\_inno_{it} = a_0 + a_1 env\_aud_{it-1} + \sum a_t X_{it} + \gamma_t + \eta_i + \varepsilon_{it} \quad (2)$$

where *i* denotes enterprise (*i* = 1,2, …, 437), and *t* means time (*t* = 1,2, …, 12). The *env_aud* means environmental audit, *tech_intro* means technology introduction, *tech_co* means technology cooperation, and *ind_inno* means independent innovation. Other parts are control variables and error term. This study also controls time fixed effect and individual fixed effect.

Empirical Results and Discussion

Descriptive Statistics

Table 1 presents the descriptive statistics of the variables. Columns 2 presents the mean values of the whole sample. The standard deviation is reported in column 3. Columns 4 and 5 report the minimum value and maximum value. The numbers on innovation are markedly different.

Baseline Regression and Discussion

Table 3 presents the results of baseline regression. Fixed-effect models are employed to assess the impact of environmental auditing on technology introduction and technology cooperation, negative binomial regression is used to test the impact of environmental audit on independent innovation. Time fixed effects and individual fixed effects are also considered to avoid estimation bias. It presents that environmental audit has positive impacts on technology introduction, technology cooperation and independent innovation in the long time as well as that in the short time. This means that environmental audit is one of the important driving forces for enterprises to improve the negative externalities of production. Environmental audit is a

Table 1. Variables and explanation.

Variables	Abbreviation	Measurement
environmental audit	*env_aud*	Enterprise publishes its environmental audit report (=1)
technology introduction	*tech_intro*	Expenditure on purchasing external green technology
technology cooperation	*tech_co*	Payment to a university or institute for green technology
independent innovation	*ind_inno*	The numbers of green patent application
firm's age	*age*	The length of time from establishment to the present
firm size	*size*	Total assets
State-owned enterprise	*owner*	State-owned enterprise (=1)
return on assets	*roa*	Return on assets
debt-to-assets ratio	*debt*	Total debt/total assets
political title	*title*	Chairman or managing director has a political title (=1)

kind of active environmental protection behavior of enterprises, aiming at reducing the impact of enterprise activities on the environment. At the same time, environmental audit can also identify the potential risk of administrative penalties due to environmental damage and assess the cost of environmental compensation. Firms need to allocate resources and adjust technical strategies to meet environmental requirements to avoid administrative penalties or higher environmental costs. As a result, companies will choose ways to upgrade their

Table 2. Descriptive statistics.

Variables	Mean	St.D.	Min	Max
env_aud	0.552	0.473	0.000	1.000
tech_intro	5.837	1.021	3.045	10.516
tech_co	0.877	2.117	0.000	6.826
ind_inno	5.571	22.365	0.000	1326.000
age	18.377	4.525	3.213	28.823
size	25.882	2.822	16.517	36.773
owner	0.589	0.417	0.000	1.000
roa	0.042	0.091	-2.772	0.619
debt	0.532	0.196	0.317	0.876
title	0.634	0.467	0.000	1.000

Table 3. Baseline regression.

	tech_intro	*tech_co*	*ind_inno*	*tech_intro*	*tech_co*	*ind_inno*
env_aud	0.062**	0.027**	0.622***			
	(0.032)	(0.010)	(1.332)			
env_aud_{t-1}				0.385**	0.239**	0.412**
				(0.047)	(0.026)	(0.998)
age	0.003*	0.012*	1.721**	0.007*	0.036*	0.963**
	(0.153)	(0.176)	(0.758)	(0.401)	(0.267)	(0.663)
size	11.541*	13.536	9.737*	16.665**	19.358*	9.828
	(3.471)	(5.528)	(2.518)	(2.494)	(3.251)	(2.102)
owner	0.132	0.136***	2.362	0.223	0.241**	1.787**
	(0.154)	(0.154)	(0.322)	(0.212)	(0.266)	(0.296)
roa	-3.335*	-2.223	0.847**	-3.757	1.332*	0.659**
	(0.288)	(0.312)	(0.616)	(0.289)	(0.161)	(0.433)
debt	-0.003**	-0.003**	-0.756*	-0.001**	-0.001**	-0.284*
	(0.202)	(0.199)	(0.236)	(0.177)	(0.176)	(0.132)
title	0.788*	0.636**	3.335*	0.537**	0.532*	2.087*
	(0.201)	(0.179)	(0.278)	(0.144)	(0.144)	(0.216)
con_s	-26.289***	18.557	-33.685*	-30.776	-16.338**	-30.026
	(0.573)	(1.236)	(0.944)	(1.223)	(0.772)	(0.813)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	5244	5244	5244	5244	5244	5244

*Notes: *** p<0.01, ** p<0.05, * p<0.1.*

technology according to the urgency of environmental protection.

We also find the influence of some control variables on enterprise technology strategy. The older an enterprise is, the more technical reserves and social resources it has, which has a significant normal impact on the enterprise's various technological strategies in both the long and short term. High debt ratio hinders the technological investment of enterprises and has a negative impact on their technological strategy. The firms whose executives are politically connected are more likely to upgrade technology and diversify their innovation strategies.

Robustness Test

Alternative Variables

To test the robustness of significance in the baseline regression results, we conducted regression again after using new independent variables and new dependent variables. Environmental audit *(env_aud)* is completely replaced with environmental management system *(ems)* as an independent variable according to Wang, et al. [64]. The firm who implements environmental management system is equal to 1, and other are equal to 0. At the same time, technology introduction (*tech_intro*) measured by expenditures on external technology is replaced with number of external patents purchased *(n_epp)*. The number of patents applied jointly by enterprise and college *(n_pa)* substitutes for technology cooperation *(tech_co)*. We use number of granted patents *(n_gp)* as a proxy variable for independent innovation *(ind_inno)* which is measured by the numbers of patent application. Table 4 presents the results according to alternative variables. We find that the results in Table 4 are consistent with the significance of baseline regression from Table 3.

Changing Time Windows

We test the robustness of the significance of the baseline regression by changing time windows according to Li [2]. The results in Table 4 are from two randomly selected time periods between 2009 and 2020 that are from 2010 to 2016 and from 2015 to 2020, respectively. The results in Table 5 are consistent with the significance of baseline regression from Table 3.

Table 4. Results based on alternative variables.

	n_epp	*n_pa*	*n_gp*	*n_epp*	*n_pa*	*n_gp*
ems	0.082*	0.035**	0.827*			
	(0.042)	(0.013)	(1.771)			
ems_{t-1}				1.270**	0.788**	1.359*
				(0.098)	(0.054)	(2.095)
age	0.003**	0.015	2.288**	0.014**	0.075	2.022*
	(0.203)	(0.234)	(1.008)	(0.842)	(0.560)	(1.392)
size	5.349**	4.002***	0.950***	3.996***	4.651***	2.638***
	(0.616)	(0.352)	(1.348)	(1.537)	(1.327)	(0.614)
owner	0.175**	0.180*	3.141**	0.468*	0.506*	3.752***
	(0.204)	(0.204)	(0.428)	(0.445)	(0.558)	(0.609)
roa	1.435*	1.956	1.126	0.889**	0.797	1.383
	(0.383)	(0.414)	(0.819)	(0.606)	(0.338)	(0.909)
debt	-0.003**	-0.099*	1.005*	0.002	0.002	-0.596*
	(0.268)	(0.264)	(0.313)	(0.371)	(0.369)	(0.277)
title	1.048*	0.845*	4.435*	1.127*	1.117**	4.382*
	(0.267)	(0.238)	(0.369)	(0.302)	(0.302)	(0.453)
con_s	4.964*	2.680	4.801	6.629**	3.309	11.0546*
	(0.762)	(1.643)	(1.255)	(2.568)	(1.621)	(2.7073)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	5244	5244	5244	5244	5244	5244

Notes: *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Results based on changing time windows.

	2010-2016			2015-2020		
	tech_intro	*tech_co*	*ind_inno*	*tech_intro*	*tech_co*	*ind_inno*
env_aud	0.054*	0.025**	1.791**			
	(0.028)	(0.009)	(0.836)			
env_aud_{t-1}				0.515*	0.291*	2.154**
				(0.062)	(0.031)	(0.219)
age	0.064**	0.152*	0.568*	0.093**	0.392*	0.369*
	(0.346)	(0.689)	(0.184)	(0.534)	(0.574)	(0.674)
size	1.156*	1.456	2.042	2.331	2.167**	1.400
	(0.054)	(0.306)	(0.251)	(0.066)	(0.622)	(0.346)
owner	0.116**	0.130**	3.802*	0.298**	0.294***	2.346*
	(0.135)	(0.147)	(0.927)	(0.284)	(0.324)	(1.516)
roa	2.934	2.134**	2.439	5.034**	1.625**	3.446
	(0.253)	(0.299)	(1.774)	(0.387)	(0.196)	(1.264)
debt	-0.026	-0.028*	1.772*	-0.234	-0.122*	1.453
	(0.177)	(0.191)	(0.679)	(0.237)	(0.214)	(0.690)
title	0.693**	0.610**	9.604**	0.719**	0.649*	10.915***
	(0.176)	(0.171)	(0.800)	(0.192)	(0.175)	(1.129)
con_s	-23.134*	-17.814*	-27.012	-21.239	-19.932*	-25.036**
	(0.504)	(1.186)	(2.718)	(1.638)	(0.941)	(4.251)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	3059	3059	3059	2622	2622	2622

*Notes: *** p<0.01, ** p<0.05, * p<0.1.*

Random Selection of Samples

We test the robustness of the significance of the baseline regression by random selection of samples according to Hu et al., [5]. We randomly selected 100-350 samples for regression analysis and examine the impacts of environmental auditing on different technical strategies. In order to ensure that the sample selection is random, we adopt the results of random selection by multiple people independently. It is found that the results from the random sample still support the significance of baseline regression in the short and long term. Therefore, we believe that the results of baseline regression are robust. The results are presented in Table 6.

Heterogeneity Analysis and Discussion

Generally, the design of an enterprise's green strategy depends on the industry that the enterprise belongs to and business type of the enterprise. Environmental compliance and public trust are the primary goals for the listed companies within high-pollution industries in China. However, for those enterprises with low environmental sensitivity, environmental regulation may not bring significant pressure for environmental compliance. Therefore, enterprises with different level of pollution would design different green technology strategies when they face environmental audit. According to the above analysis, we divided all the samples into two groups, namely the high-pollution group and the low-pollution group. Table 7 presents the results from high-pollution group.

Table 7 demonstrates the impact of environmental audit on green innovative strategy of enterprise with high pollution. According to industry classification code, there are 154 firms that belong to high-pollution industry. We find that environmental audit has short-term impacts on technology introduction and technology cooperation and no impact on short-time independent innovation and innovative strategy in the long time. Environmental legitimacy is the minimum requirement for the normal operation of enterprises with high pollution. Enterprises

Table 6. Results based on random selection of samples.

	tech_intro	*tech_co*	*ind_inno*	*tech_intro*	*tech_co*	*ind_inno*
env_aud	2.170**	0.945**	2.177**			
	(1.126)	(0.150)	(1.462)			
env_aud_{t-1}				2.039**	0.645**	1.112**
				(1.269)	(0.070)	(1.694)
age	0.547**	2.166	3.780	1.266**	6.484	4.349
	(1.377)	(1.584)	(1.822)	(1.609)	(1.403)	(1.967)
size	3.462***	4.060**	2.921**	4.999**	5.807***	2.948*
	(1.041)	(1.658)	(0.755)	(1.648)	(2.475)	(1.230)
owner	0.099	0.102**	2.771***	0.167*	0.180**	0.340
	(0.023)	(0.173)	(0848)	(0.031)	(0.039)	(0.043)
roa	0.667**	-0.444**	0.169*	0.751**	-0.266**	0.131
	(0.806)	(0.873)	(1.724)	(0.809)	(0.450)	(1.212)
debt	-0.456*	-0.882***	-11.347***	-0.153**	-0.615***	-1.606**
	(0.105)	(0.348)	(3.122)	(0.092)	(0.552)	(0.068)
title	0.409**	6.330*	1.734**	0.279**	0.276***	1.085***
	(0.104)	(1.093)	(0.144)	(0.074)	(0.074)	(0.112)
con_s	-3.670*	6.649**	-6.516*	3.003	-8.495*	-5.613***
	(0.297)	(0.642)	(0.490)	(0.435)	(0.401)	(0.422)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	3324	1872	3720	2585	1404	3996

*Notes: *** p<0.01, ** p<0.05, * p<0.1.*

will receive strict administrative penalties if they fail to meet environmental requirements. Therefore, meeting environmental protection requirements in the shortest time has the least impact on enterprise operating costs. For high-pollution enterprises, after meeting the basic environmental requirements, they will not invest more funds into environmental technology development to achieve higher environmental performance. Most high-pollution enterprises belong to basic resource industries that these industries have mature pollution control technologies, and the development cycle of new technologies is longer and the cost is higher. Enterprises within these industries prefer to introduce external technologies for upgrading green technologies rather than independent innovation. Technology introduction and technology cooperation have lower cost and risk in comparison to independent innovation for these enterprises with high pollution.

Table 8 reports the impact of environmental audit on green innovative strategy of enterprise with low pollution. It finds that there is a positive impact of environmental audit on independent innovation in the short and long term. There is also a long-time and positive impact on technology introduction and technology cooperation. Low polluted enterprises have lower environmental pressures and may devote more resources to independent innovation. These enterprises pay more attention to innovation and achieve innovation through external technology in the long term. Firms are better able to allocate resources and reduce innovation risk and uncertainty by cooperating with universities or introducing external technology. Technology introduce or technology cooperation can also improve the level of technology reserves of enterprises in the long time and provide support for future innovation.

Conclusions and Policy Implication

Conclusions

This study examines the impact of environmental audit on green innovative strategy of enterprise. Samples and data from 437 listed companies in China are collected from 2009 to 2020. Green innovative strategy of enterprise is divided into technology introduction, technology cooperation and independent innovation. Research samples are divided into two groups according

Table 7. The impact of environmental audit on green innovative strategy of high polluted enterprise.

	tech_intro	*tech_co*	*ind_inno*	*tech_intro*	*tech_co*	*ind_inno*
env_aud	0.757**	0.477**	0.622			
	(0.007)	(0.015)	(1.332)			
env_aud_{t-1}				0.188	0.239	0.412
				(0.022)	(0.026)	(0.998)
age	1.598*	0.039*	6.629**	4.637*	0.015*	2.924**
	(1.514)	(0.109)	(1.368)	(2.776)	(0.032)	(0.228)
size	20.341*	14.187	17.782*	8.389**	30.847*	10.378
	(5.311)	(4.266)	(4.638)	(5.526)	(7.796)	(3.393)
owner	1.584**	1.632***	8.344***	2.676***	2.892**	1.444***
	(0.816)	(0.729)	(2.706)	(1.123)	(1.409)	(0.337)
roa	-2.134**	-1.422	0.542	-2.404	0.852**	0.421
	(1.114)	(1.207)	(2.383)	(1.118)	(0.623)	(1.675)
debt	-0.175	-0.326*	-44.127**	-0.058	-0.058	-6.574*
	(0.178)	(0.376)	(6.209)	(0.156)	(0.155)	(0.695)
title	2.088**	1.685*	8.837**	1.423*	1.409**	5.530**
	(0.639)	(0.569)	(0.884)	(0.457)	(0.457)	(0.686)
con_s	-16.825**	11.876	-21.558**	-19.696**	-10.456	-19.216
	(2.160)	(4.659)	(11.558)	(4.610)	(2.910)	(3.065)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	1848	1848	1848	1848	1848	1848

Notes: *** p<0.01, ** p<0.05, * p<0.1.

to the pollution level for examine heterogeneity. Some conclusions can draw from empirical results. First, voluntary environmental regulation has a significantly positive impact on green innovative strategy in both the short and long term. This conclusion is consistent with the studies by Ren, et al. [65], Ofori, et al. [66] and Bu, et al. [19]. It also directly confirms and supports the "Weak Porter Hypothesis". Voluntary environmental regulation strengthens the self-examination of enterprises' environmental behavior and drives them to design reasonable green innovative strategy. Second, enterprises with high pollution are more inclined to meet environmental requirements rather than innovation. The result reports that environmental audit can only trigger through technology introduction and technology cooperation in the short time. This explains the inconsistent research conclusion on the Porter Hypothesis. For those firms with high pollution, they usually belong to traditional industries that engage in the extraction and production of basic resources. They have heavy assets and higher environmental costs, which makes them more inclined to meet environmental standards in the short term to avoid being penalized. Therefore, these enterprises prefer to external technical resources rather than independent innovation. When researchers select high-polluting enterprises as research samples, they may get the opposite conclusion than the results of the Porter Hypothesis. Third, voluntary environmental regulation is more effective for low-polluting enterprises. Flexible environmental policies can stimulate the initiative of low-polluting enterprises and drive their independent innovation. Moreover, in the long run, environmental regulations have a smaller impact on the production costs of low-polluting enterprises and do not have a crowding out effect on R&D investment because of better resource allocation.

Policy Implication

The findings have important management and policy implications for the practice of environmental auditing. Enterprises should regard environmental audit as an important part of development strategy and implement green innovative strategy according to environmental audit. At the same time, enterprises should also obtain the recognition of government, market, and investor through environmental audit, and realize environmental

Table 8. The impact of environmental audit on green innovative strategy of low polluted enterprise.

	tech_intro	*tech_co*	*ind_inno*	*tech_intro*	*tech_co*	*ind_inno*
env_aud	1.912	0.832	19.182***			
	(0.986)	(0.308)	(4.888)			
env_audt-1				1.524**	0.946***	1.631**
				(0.186)	(0.102)	(3.952)
age	0.076**	0.307*	44.126	0.179	0.923*	4.691
	(0.480)	(0.552)	(2.380)	(1.259)	(0.383)	(2.081)
size	3.462***	4.060***	2.921	4.999***	5.807**	2.948
	(0.815)	(1.299)	(0.591)	(1.291)	(1.938)	(0.963)
owner	0.279**	0.287	4.994*	0.471**	0.509	3.778
	(0.325)	(0.325)	(0.680)	(0.448)	(0.562)	(0.613)
roa	11.194**	7.462*	2.843*	12.611*	4.471**	2.212**
	(1.296)	(1.404)	(2.772)	(1.300)	(0.724)	(1.948)
debt	-0.031**	-7.662**	-8.040*	-0.010**	-0.598**	-3.006***
	(0.467)	(3.605)	(0.546)	(0.409)	(0.407)	(0.305)
title	1.823**	0.472**	1.718*	0.024**	1.231	4.830**
	(0.465)	(0.014)	(0.643)	(0.033)	(0.333)	(0.499)
con_s	-60.845**	42.950*	-77.9639	-7.2311*	-37.8143	-69.4952***
	(13.262)	(12.860)	(25.184)	(2.830)	(10.786)	(19.881)
year	Y	Y	Y	Y	Y	Y
firm	Y	Y	Y	Y	Y	Y
obs	3396	3396	3396	3396	3396	3396

Notes: *** p<0.01, ** p<0.05, * p<0.1.

legitimacy and competitive advantage. The government should design and implement differentiated environmental policies to guide enterprises to take the initiative to operate environmental auditing, especially to support high polluted enterprises to achieve emission reduction and technology upgrading through financial incentives.

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Conflict of Interest

The authors report there are no competing interests to declare.

References

1. BOWEN F., TANG S., PANAGIOTOPOULOS P. A classification of information-based environmental regulation: Voluntariness, compliance and beyond, Science of The Total Environment, **712**, 135571 **2020**.
2. LI C. How does environmental regulation affect different approaches of technical progress? – Evidence from China's industrial sectors from 2005 to 2015, Journal of Cleaner Production, **209**, 572, **2019**.
3. YUAN B., XIANG Q. Environmental regulation, industrial innovation and green development of Chinese manufacturing: Based on an extended CDM model, Journal of Cleaner Production, **176**, 895, **2018**.
4. REN S., YANG X., HU Y., CHEVALLIER J. Emission trading, induced innovation and firm performance, Energy Economics, **112**, 106157, **2022**.
5. HU Y., REN S., WANG Y., CHEN X. Can carbon emission trading scheme achieve energy conservation and emission reduction? Evidence from the industrial sector in China, Energy Economics, **85**, 104590, **2020**.
6. JIANG Z., WANG Z., LAN X. How environmental regulations affect corporate innovation? The coupling mechanism of mandatory rules and voluntary management, Technology in Society, **65**, 101575, **2021**.

7. AMBEC S., COHEN M.A., ELGIE S., LANOIE P. The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?, Review of Environmental Economics and Policy, **7**, 2, **2013**.
8. BECKER R.A., PASURKA C., SHADBEGIAN R.J. Do environmental regulations disproportionately affect small businesses? Evidence from the Pollution Abatement Costs and Expenditures survey, Journal of Environmental Economics and Management, **66**, 523, **2013**.
9. PORTER M.E., VAN DER LINDE C. Toward a New Conception of the Environment-Competitiveness Relationship, Journal of Economic Perspectives, **9**, 97, **1995**.
10. GUO M., WANG H., KUAI Y. Environmental regulation and green innovation: Evidence from heavily polluting firms in China, Finance Research Letters, 103624, **2022**.
11. YU Y., ZHANG N. Environmental regulation and innovation: Evidence from China, Global Environmental Change, **76**, 102587, **2022**.
12. MA H., LI L. Could environmental regulation promote the technological innovation of China's emerging marine enterprises? Based on the moderating effect of government grants, Environmental Research, **202**, 111682, **2021**.
13. CAI X., ZHU B., ZHANG H., LI L., XIE M. Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies, Science of The Total Environment, **746**, 140810, **2020**.
14. SHARIF A., KOCAK S., KHAN H.H.A., UZUNER G., TIWARI S. Demystifying the links between green technology innovation, economic growth, and environmental tax in ASEAN-6 countries: The dynamic role of green energy and green investment, Gondwana Research, **115**, 98, **2023**.
15. DONG K., SHAHBAZ M., ZHAO J. How do pollution fees affect environmental quality in China?, Energy Policy, **160**, 112695, **2022**.
16. ZHAO X., LU W., WANG W., HU S. The impact of carbon emission trading on green innovation of China's power industry, Environmental Impact Assessment Review, **99**, 107040, **2023**.
17. XU L., YANG L., LI D., SHAO S. Asymmetric effects of heterogeneous environmental standards on green technology innovation: Evidence from China, Energy Economics, **117**, 106479, **2023**.
18. LIU N., TANG S.-Y., ZHAN X., LO C.W.-H. Policy uncertainty and corporate performance in government-sponsored voluntary environmental programs, Journal of Environmental Management, **219**, 350, **2018**.
19. BU M., QIAO Z., LIU B. Voluntary environmental regulation and firm innovation in China, Economic Modelling, **89**, 10, **2020**.
20. ZHOU D., YUAN S., XIE D. Voluntary environmental regulation and urban innovation: Evidence from low-carbon pilot cities program in China, Technological Forecasting and Social Change, **175**, 121388, **2022**.
21. POWELL D.M.W. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields, American Sociological Review, **48**, 147, **1983**.
22. SUCHMAN C. M. Managing Legitimacy: Strategic and Institutional Approaches, Academy of Management Review, **20**, 571, **1995**.
23. BARBERA A.J., MCCONNELL V.D. The impact of environmental regulations on industry productivity: Direct and indirect effects, Journal of Environmental Economics and Management, **18**, 50, **1990**.
24. ZHANG P., ZHOU D., GUO J. Policy complementary or policy crowding-out? Effects of cross-instrumental policy mix on green innovation in China, Technological Forecasting and Social Change, **192**, 122530, **2023**.
25. OZDEMIR S., CARLOS FERNANDEZ DE ARROYABE J., SENA V., GUPTA S. Stakeholder diversity and collaborative innovation: Integrating the resource-based view with stakeholder theory, Journal of Business Research, **164**, 113955, **2023**.
26. DANG V.T., WANG J. Building competitive advantage for hospitality companies: The roles of green innovation strategic orientation and green intellectual capital, International Journal of Hospitality Management, **102**, 103161, **2022**.
27. ZAMEER H., WANG Y., YASMEEN H. Reinforcing green competitive advantage through green production, creativity and green brand image: Implications for cleaner production in China, Journal of Cleaner Production, **247**, 119119, **2020**.
28. REN X., XIA X., TAGHIZADEH-HESARY F. Uncertainty of uncertainty and corporate green innovation – Evidence from China, Economic Analysis and Policy, **78**, 634, **2023**.
29. ZHOU H., ZHU X., DAI J., WU W. Innovation evolution of industry-university-research cooperation under low-carbon development background: In case of 2 carbon neutrality technologies, Sustainable Energy Technologies and Assessments, **55**, 102976, **2023**.
30. ZHANG R., FU Y. Technological progress effects on energy efficiency from the perspective of technological innovation and technology introduction: An empirical study of Guangdong, China, Energy Reports, **8**, 425, **2022**.
31. TOOULI G., GEORGIOU A., WESTBROOK J. Changes, disruption and innovation: An investigation of the introduction of new health information technology in a microbiology laboratory, Journal of Pathology Informatics, **3**, 16, **2012**.
32. NGUYEN P.-H., TRAN L.-C., NGUYEN H.B.-D., HO T.P.-T., DUONG Q.-A., TRAN T.-N. Unlocking the potential of open innovation through understanding the interrelationship among key determinants of FDI attractiveness, Journal of Open Innovation: Technology, Market, and Complexity, **9**, 100021, **2023**.
33. VUJANOVIĆ N., RADOŠEVIĆ S., STOJČIĆ N., HISARCIKLILAR M., HASHI I. FDI spillover effects on innovation activities of knowledge using and knowledge creating firms: Evidence from an emerging economy, Technovation, **118**, 102512, **2022**.
34. MALLETT A., Social acceptance of renewable energy innovations: The role of technology cooperation in urban Mexico, Energy Policy, **35**, 2790, **2007**.
35. MENDI P., MONER-COLONQUES R., SEMPERE-MONERRIS J.J. Cooperation for innovation and technology licensing: Empirical evidence from Spain, Technological Forecasting and Social Change, **154**, 119976, **2020**.
36. LYU C., XIE Z., LI Z. Market supervision, innovation offsets and energy efficiency: Evidence from environmental pollution liability insurance in China, Energy Policy, **171**, 113267, **2022**.
37. JAFFE A., PALMER K. Environmental Regulation and Innovation: A Panel Data Study, Review of Economics and Statistics, **79**, 610, **2006**.
38. SCHOT J., STEINMUELLER W.E. Three frames for innovation policy: R&D, systems of innovation and transformative change, Research Policy, **47**, 1554, **2018**.

39. CHAKRABORTY P., CHATTERJEE C. Does environmental regulation indirectly induce upstream innovation? New evidence from India, Research Policy, **46**, 939, **2017**.
40. YANG C.H., TSENG Y.H., CHEN C.P. Environmental regulations, induced R&D, and productivity: Evidence from Taiwan's manufacturing industries, Resource and Energy Economics, **34**, 514, **2012**.
41. KESIDOU E., WU L. Stringency of environmental regulation and eco-innovation: Evidence from the eleventh Five-Year Plan and green patents, Economics Letters, **190**, 109090, **2020**.
42. LI X., DU K., OUYANG X., LIU L. Does more stringent environmental regulation induce firms' innovation? Evidence from the 11th Five-year plan in China, Energy Economics, **112**, 106110, **2022**.
43. XU Y., DONG Z., WU Y. The spatiotemporal effects of environmental regulation on green innovation: Evidence from Chinese cities, Science of The Total Environment, **876**, 162790, **2023**.
44. ZHANG D., Environmental regulation, green innovation, and export product quality: What is the role of greenwashing?, International Review of Financial Analysis, **83**, 102311, **2022**.
45. TONG L., CHIAPPETTA JABBOUR C.J., BELGACEM S.B., NAJAM H., ABBAS J. Role of environmental regulations, green finance, and investment in green technologies in green total factor productivity: Empirical evidence from Asian region, Journal of Cleaner Production, **380**, 134930, **2022**.
46. WANG F., The intermediary and threshold effect of green innovation in the impact of environmental regulation on economic Growth: Evidence from China, Ecological Indicators, **153**, 110371, **2023**.
47. BECKSTEDDE E., CORREA RAMíREZ M., COSSENT R., VANSCHOENWINKEL J., MEEUS L. Regulatory sandboxes: Do they speed up innovation in energy?, Energy Policy, **180**, 113656, **2023**.
48. YANG M., CHEN H., LONG R., SUN Q., YANG J. How does government regulation promote green product diffusion in complex network? An evolutionary analysis considering supply side and demand side, Journal of Environmental Management, **318**, 115642, **2022**.
49. LIU M., LI Y. Environmental regulation and green innovation: Evidence from China's carbon emissions trading policy, Finance Research Letters, **48**, 103051, **2022**.
50. DE BEULE F., DEWAELHEYNS N., SCHOUBBEN F., STRUYFS K., VAN HULLE C. The influence of environmental regulation on the FDI location choice of EU ETS-covered MNEs, Journal of Environmental Management, **321**, 115839, **2022**.
51. DONG Y., TIAN J., YE J. Environmental regulation and foreign direct investment: Evidence from China's outward FDI, Finance Research Letters, **39**, 101611, **2021**.
52. PAN A., QIN Y., LI H., ZHANG W., SHI X. Can environmental information disclosure attract FDI? Evidence from PITI project, Journal of Cleaner Production, **403**, 136861, **2023**.
53. JABBOUR C.J.C. Environmental training and environmental management maturity of Brazilian companies with ISO14001: empirical evidence, Journal of Cleaner Production, **96**, 331, **2015**.
54. XU Z., DAI Y., LIU W. Does environmental audit help to improve water quality? Evidence from the China National Environmental Monitoring Centre, Science of The Total Environment, **823**, 153485, **2022**.
55. INOUE E., ARIMURA T.H., NAKANO M. A new insight into environmental innovation: Does the maturity of environmental management systems matter?, Ecological Economics, **94**, 156, **2013**.
56. YU L., LI H., WANG Z., DUAN Y. Technology imports and self-innovation in the context of innovation quality, International Journal of Production Economics, **214**, 44, **2019**.
57. ASIMAKOPOULOS G., REVILLA A., RODRíGUEZ A. International R&D sourcing, innovation and firm age: The advantage of 'born-international sourcers', Technovation, **122**, 102662, **2023**.
58. SKORDOULIS M., NTANOS S., KYRIAKOPOULOS, G.L. ARABATZIS G., GALATSIDAS S., CHALIKIAS M. Environmental Innovation, Open Innovation Dynamics and Competitive Advantage of Medium and Large-Sized Firms, Journal of Open Innovation: Technology, Market, and Complexity, **6**, 195, **2020**.
59. YU Z., SHEN Y., JIANG S. The effects of corporate governance uncertainty on state-owned enterprises' green innovation in China: Perspective from the participation of non-state-owned shareholders, Energy Economics, **115**, 106402, **2022**.
60. HOLZNER B., WAGNER M. Linking levels of green innovation with profitability under environmental uncertainty: An empirical study, Journal of Cleaner Production, **378**, 134438, **2022**.
61. YANG Z., CHEN Z., SHI Q., YAN B. Does outward foreign direct investment increase debt ratio? Firm-level evidence from China, Structural Change and Economic Dynamics, **57**, 1, **2021**.
62. QU F., XU L., HE C. Leverage effect or crowding out effect? Evidence from low-carbon city pilot and energy technology innovation in China, Sustainable Cities and Society, **91**, 104423, **2023**.
63. ZHANG C., ZHOU B., TIAN X. Political connections and green innovation: The role of a corporate entrepreneurship strategy in state-owned enterprises, Journal of Business Research, **146**, 375, **2022**.
64. WANG L., SHANG Y., LI C. How to improve the initiative and effectiveness of enterprises to implement environmental management system certification?, Journal of Cleaner Production, **404**, 137013, **2023**.
65. REN S., HE D., YAN J., ZENG H., TAN J. Environmental labeling certification and corporate environmental innovation: The moderating role of corporate ownership and local government intervention, Journal of Business Research, **140**, 556, **2022**.
66. OFORI E.K., LI J., RADMEHR R., ZHANG J., SHAYANMEHR S. Environmental consequences of ISO 14001 in European economies amidst structural change and technology innovation: Insights from green governance dynamism, Journal of Cleaner Production, **411**, 137301, **2023**.