Environmental Regulation and Green Innovation of Enterprises -- Retest of "Porter Hypothesis" Based on the Frequency of Environmental Protection Words

Xuan Guo

School of Economics, Hefei University of Technology, Hefei 230000, China.

FrancescaGuo@163.com

Abstract. Based on the sample data of Shanghai and Shenzhen A-share listed companies in the heavy pollution industry from 2012 to 2021, this paper empirically examines the impact of environmental regulation on the level of green innovation of enterprises by using the frequency of environmental protection words in the work reports of prefecture-level city governments as the proxy variable of environmental regulation. This study finds that government regulation significantly improves the level of green innovation of enterprises, supporting the "Porter Hypothesis", and the promotion effect is more significant for non-state enterprises. This study plays an important role in improving the policy effect of environmental regulation, and puts forward some policy suggestions on how to reduce environmental pollution while promoting economic growth.

Keywords: Environmental regulation; Green innovation of enterprises; The nature of property rights; The frequency of environmental protection words.

1. Introduction

More than forty years of reform and opening-up, China's economy has developed rapidly. Since 2010, China has ranked the first manufacturing country in the world for 12 consecutive years. However, the rapid economic growth of our country is produced at the cost of repeated construction, energy consumption and environmental damage. The air pollution, water environment pollution, land desertification and other problems that accompany it not only affect the sustainable development of the manufacturing industry, but also seriously threaten the public health of our country. According to the Bulletin on China's Ecological Environment in 2021 issued by the Ministry of Ecology and Environment, China's air pollution situation is still severe: in 2021, 146 of the 339 cities at and above the prefecture level in China exceeded the standard, accounting for 43.1%. Meanwhile, according to the global environmental performance index (EPI) report jointly released by Yale University and other research institutions, China ranked 177th and 120th among the 180 countries and regions participating in the evaluation in 2018 and 2020 respectively.

In order to curb the continuous deterioration of the ecological environment, China has increasingly attached importance to environmental protection, continuously deepened the reform of the ecological civilization system, and enhanced the intensity of environmental regulation. Since the 18th CPC National Congress in 2012, socialism with Chinese characteristics has entered a new era. Facing the urgent need of China's ecological environment protection, general secretary Xi Jinping stood at the strategic height of realizing the sustainable development of the Chinese nation, incorporating the construction of ecological civilization into the important contents of the "five in one" overall layout and the "four comprehensives" strategic layout, and creatively put forward the idea that protecting the ecological environment is to protect the productive forces, and green water and green mountains are golden mountains and silver mountains. At the same time, rules and regulations related to environmental protection have been introduced in China. In 2015, the "strictest" environmental protection law in history was promulgated and implemented. The law stipulates the obligations of enterprises such as self-monitoring and information disclosure, as well as new measures such as daily penalties and joint liability. Until 2017, the report of the 19th National Congress of the Communist Party of China also focused on the key areas of environmental protection and put forward the key tasks and measures related to all aspects of pollution control in China. Since January 2018, in order

to protect and improve the ecological environment and reduce the emission of pollutants, the Environmental Protection Tax Law of the People's Republic of China has been formally implemented in China. In July 2018, the State Council publicly released the Three-year Action Plan for Winning the Blue-Sky Protection Campaign. By September 2020, China has clearly put forward the goals of "emission peak" in 2030 and "carbon neutrality" in 2060.

The increasingly strict environmental regulation has caused widespread concern in the academic community. Nevertheless, the existing studies haven't reached an agreement on the impact of environmental regulation on green innovation of enterprises. This paper believes that the important reason lies in the endogenous problem caused by the variable setting and measurement bias. Some studies mainly use the regional pollutant emission degree as the proxy variable of environmental regulation (Li Ling et al., 2012; Yin Baoqing, 2012; Li Bin et al., 2013; Wang Fengzheng et al., 2015). However, the indicator may have the serious problems of missing variables and reverse causality. Therefore, this paper uses the frequency of environmental protection words in municipal government work reports as the proxy variable of environmental regulation to reexamine the impact of environmental regulation.

2. Literature Review

Through combing the relevant literature, many scholars believe that environmental regulation can promote the green technology innovation of enterprises. Porter (1991), a representative scholar, put forward the "Porter Hypothesis", believing that appropriate environmental regulation can promote enterprises to carry out more innovation activities. Brunnermeier and Cohen (2003) used panel data of American manufacturing industry to find that there was a positive relationship between pollution control expenditure and the number of environmental patent applications. Based on the data of seven OECD countries, Frondel et al. (2007) found that strict environmental regulation policies had a positive correlation with enterprise green technology innovation. Zhu and Wu (2022) used the panel data of China's coastal areas from 2005 to 2015 and found that environmental laws and regulations significantly promoted the growth of the overall number of patent applications in coastal areas. Based on the company data of heavy pollution industries listed in Shenzhen and Shanghai A-shares from 2008 to 2013, domestic scholars Xie Maohua et al. (2014) measured the intensity of environmental regulation by using the change degree of environmental protection investment and "three wastes" emissions of enterprises, and found that environmental regulation could promote the environmental protection R&D investment of China's heavy pollution industries. Jing Weimin and Zhang Lu (2014) used the panel data of 33 industrial industries in China from 2003 to 2010 to find that strengthening R&D subsidies and environmental taxes had a positive impact on the progress of industrial green technology in China. Wu Libo et al. (2021) made use of the enterprise panel data from 2005 to 2009 and found that the number of green patents of wastewater discharge enterprises had significantly increased after they were included in the national key monitoring list. Liu Jinke and Xiao Yiyang (2022) found that the environmental protection tax with higher regulation intensity could effectively promote the green innovation activities of enterprises based on the green patent data of micro enterprises and the triple difference method. Wang Xiaoqi et al. (2020) took the data of China's A-share listed companies from 2007 to 2016 as a sample, and the research results showed that the enhancement of the level of environmental regulation, which was the implementation of the new environmental protection law, could exert the porter effect and "force" heavy polluting enterprises to carry out green innovation.

Some scholars believe that environmental regulation has a restraining effect on green technology innovation of enterprises. Palmer et al. (1995) questioned the "Porter Hypothesis", believing that strict environmental regulation made the control cost of enterprises higher than the benefits brought by enterprises adopting green innovation technology. Gray and Shadbegian (2003) used the data of 116 pulp and paper mills in the United States from 1979 to 1990 and found that the increase of pollution control cost hindered the improvement of enterprise productivity. Wagner (2007) took

German manufacturing enterprises as samples and found that the implementation of environmental management system was negatively related to the patent application of enterprises. Chintrakarn (2008) used the state level panel data of 48 states from 1982 to 1994 and found that strict environmental regulations reduced the funds for green patent inventions. Domestic scholars Wang Fengzheng and Guo Xiaochuan (2015) took 12 resource-based industries in China from 2003 to 2011 as samples and used the ratio of environmental pollutant emissions to the total output value of industrial industries above designated scale to measure the intensity of environmental regulation. They found that the "Porter Hypothesis" had preconditions, that was, when the industry was large in scale and the scientific and technological activities were more invested, high-intensity environmental regulation could promote green technology innovation of resource-based industries, On the contrary, it would reduce or even produced inhibitory effect. Jin Gang and Shen Kunrong (2018) found that when the government implemented environmental regulations, the existence of pollution shelters would cause some enterprises to choose transregional migration to replace local green innovation, which would inhibit long-term economic growth. From the perspective of the heterogeneity of environmental regulation tools and based on the data of listed enterprises in China's A-share heavy pollution industry from 2011 to 2017, Li Qingyuan and Xiao Zehua (2020) found that although the sewage charges "forced" the green innovation ability of enterprises, the environmental protection subsidies "crowded out" the green innovation ability of enterprises and inhibited the output of green patent achievements of enterprises due to catering to the government and opportunism. Tao Feng et al. (2021) adopted the double difference method, and they found that although the implementation of the environmental protection target responsibility system could promote the number of green patent applications, it also led to the decline of the quality of green innovation activities dominated by enterprise groups with weak innovation ability.

Another group of scholars believe that there is a nonlinear relationship between environmental regulation and enterprise green technology innovation. Yuan and Zhang (2021) used the panel data of 30 provinces in China from 2000 to 2017, and through empirical tests, they concluded that the direct impact curve of environmental regulation on industrial green total factor productivity (GTFP) conforms to the inverted "U" shape, and the distribution ratio of production factors could "reverse" the inhibitory effect of high-intensity regulations on GTFP. Shen Neng (2012), a domestic scholar, selected the proportion of industrial pollution control operation cost to industrial output value as the proxy index of environmental regulation intensity and used the panel data of China's industrial industry from 2001 to 2010. It was found that the relationship between environmental regulation intensity and environmental efficiency was inverted "U" type, with significant triple nonlinear threshold characteristics. In addition, Yin Baoqing (2012) obtained the environmental regulation intensity based on the weighted calculation of the four single indicators of SO2 removal rate, soot removal rate, dust removal rate and wastewater compliance rate, and they used the SBM model to calculate the green total factor productivity of 27 manufacturing industries in China from 2002 to 2010. The research results showed that the overall relationship between the environmental regulation intensity and the green total factor productivity of manufacturing industries presented a "U" curve, that was, with the enhancement of environmental regulation, green total factor productivity showed the changing characteristics of decreasing first and then increasing. Li Ling and Tao Feng (2012) used the data of 28 manufacturing sectors in China from 1999 to 2009, and selected three single indicators, which are wastewater discharge standard rate, sulfur dioxide removal rate and solid waste comprehensive utilization rate, to calculate the intensity of environmental regulation. They found that the relationship between the intensity of environmental regulation of heavy pollution industries and green total factor productivity and the relationship between technological progress and technological efficiency were inverted "U" types. However, the relationship between the intensity of environmental regulation of medium pollution industry and light pollution industry and these three indexes is "U" shaped. Li Bin et al. (2013) took the data of 36 industries in China from 2001 to 2010 as a sample, and also selected wastewater discharge standard rate, sulfur dioxide removal rate and comprehensive utilization rate of solid wastes to calculate the environmental regulation intensity. The research found

that there was a "threshold effect" on the impact of environmental regulation on the industrial green total factor production rate. Gao Wei et al. (2018) based on the provincial panel data of China from 2001 to 2015, measured the command control type environmental regulation by the reciprocal of the number of mining licenses approved, registered and issued, and expressed the market incentive type environmental regulation by the ratio of the investment in mine environmental recovery and treatment this year to the total investment in environmental pollution treatment. It was found that there was a "U" type nonlinear relationship between the environmental regulation intensity of command control type and market incentive type and the green level of mining industry. Du Longzheng et al. (2019) took 30 provinces and regions in China from 2001 to 2016 as samples, selected the industrial pollution source control investment for every 10,000 yuan of the total output value of industrial enterprises and the main business cost to measure the environmental regulation, and found that the relationship between China's environmental regulation and industrial Green Competitiveness conformed to the "U" type. Based on the data of listed manufacturing companies, Wang Xu and Chu Xu (2021) measured the environmental regulation faced by enterprises by the proportion of current pollution control investment in the regional gross domestic product (GDP). They found that with the gradual strengthening of environmental regulation, the same group effect of green technology innovation of enterprises tended to weaken first and then increase.

3. Research Design

3.1 Sample Selection and Data Source

In this paper, the listed companies in the heavy pollution industry of Shanghai and Shenzhen A shares from 2012 to 2021 are selected as the research objects, and the following filtering is carried out: (1) the listed companies with abnormal transactions (including ST, *ST and PT) are excluded; (2) In order to avoid the influence of abnormal values, all continuous variables were subjected to 1% tailing before and after. The data sources of this paper mainly include two parts: the environmental regulation comes from the work reports of the municipal governments and is manually sorted by the author; the green innovation data comes from the State Intellectual Property Office and is manually sorted by the author. Other control variable data at the company level mainly comes from the database of Guotaian.

With reference to Luo danglun et al. (2016) and Pan ailing et al. (2019), according to the notice on printing and distributing the classified management directory of environmental protection verification industry of listed companies issued by the Ministry of Ecology and Environment of the People's Republic of China (formerly the Ministry of Environmental Protection of the People's Republic of China) in 2008 and the guidelines for environmental information disclosure of listed companies issued in 2010. In this paper, the following industries are defined as heavy pollution industries: coal mining and washing, oil and natural gas mining, ferrous metal mining and dressing, non-ferrous metal mining and dressing, textile, leather, fur, feathers and their products and footwear, paper and paper products, petroleum processing, coking and nuclear fuel processing, chemical raw materials and chemical products manufacturing, chemical fiber manufacturing, rubber and plastic products, Non-metallic mineral products industry, ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, power and thermal production and supply industry. According to the guidance on industry classification of listed companies revised by China Securities Regulatory Commission in 2012, the codes of heavy pollution industries are B06, B07, B08, B09, C17, C19, C22, C25, C26, C28, C29, C30, C31, C32 and D44 respectively.

Referring to Liu Yunguo et al. (2016), this paper further defines the six major industries of thermal power, steel, petrochemical, cement, nonferrous metals and chemical industry proposed by the Ministry of Environmental Protection in the announcement on the implementation of special emission limits of air pollutants as heavy pollution industries in the robustness test. According to the secondary industry classification in the guidance of the China Securities Regulatory Commission in 2012, the heavy pollution industries include B07 (oil and natural gas mining industry), B08 (ferrous metal

mining and dressing industry), B09 (nonferrous metal mining and dressing industry), C25 (petroleum processing, coking and nuclear fuel processing industry), C26 (chemical raw materials and chemical products manufacturing industry), C28 (chemical fiber manufacturing industry), C29 (rubber and plastic products industry), C30 (non-metallic mineral products industry), C31 (ferrous metal smelting and rolling processing industry), C32 (nonferrous metal smelting and rolling processing industry) and D44 (power, thermal production and supply industry).

3.2 Model Specification

In order to investigate the impact of environmental regulation on the level of green innovation of enterprises, this paper constructs the following multiple linear regression model (1):

$$Invent = \alpha 1ER + \alpha iControls + \lambda \quad (1)$$

Where, invent in the formula (1) is the number of green innovation invention patents of the enterprise, representing the level of green innovation of the enterprise. ER refers to environmental regulation level, coefficient α1 reflects the impact of environmental regulation on the level of green innovation of enterprises. This paper expects the influence coefficient of ER on invent index α1 the symbol is "+", and environmental regulation has a positive role in promoting the green innovation level of enterprises.

Controls is a series of control variables. With reference to Li Wenjing et al. (2021), this paper also controls variables such as R&D investment (rd), equity concentration (ten), financial leverage (lev), institutional shareholding (io), profitability (roe) and growth capacity (growth). λ is a random disturbance term.

3.3 Variable Definition

See the following variable definition table for other control variables:

Table 1. Variable definition table

Variable types	Symbol	Meaning
Explained variables	Invent	Number of green invention patent applications
	Pinvent	Sum of green invention patent applications and green utility model patent applications
Core explanatory variables	er	Number of environmental protection word frequency in the work report of prefecture-level city government
	per	Proportion of environmental protection word frequency in the work report of prefecture-level city government
Control variables	rd	R&D investment, logarithm
	ten	Shareholding ratio of top ten shareholders
	lev	Asset liability ratio
	io	Institutional shareholding ratio
	roe	Return on net assets
	growth	Growth rate of operating revenue

Green Innovation: referring to Wang Xiaoqi et al. (2020), this paper uses Python software to search and grab the enterprise name (including the former name) and the IPC classification number listed in the International Patent Classification Green List (IPC Green Inventory, abbreviated as the List) on the website of the State Intellectual Property Office. In 2010, the World Intellectual Property Organization (WIPO) launched the List of environmentally friendly technology patents, which describes the green patent classification number (IPC classification number) in seven fields: waste management, energy conservation, nuclear energy regeneration, alternative energy, administrative regulation design, transportation and agriculture and forestry. This paper collects and counts the

number of patents that are consistent with the IPC classification number (i.e. the number of green invention patent applications) included in the list among the patents applied by listed companies year by year. In the robustness test, this paper further uses the sum of the number of green invention patent applications and the number of green utility model patent applications to measure the green innovation level of enterprises.

Environmental Regulation: referring to Chen Dengke and Chen Shiyi (2018), this paper first manually collected the government work reports of prefecture level cities from 2012 to 2021. Secondly, the text of the government work report is segmented, and the frequency of the words related to the environment is counted. Finally, the proportion of word frequency in the full text of the government report is further calculated. Environment related vocabulary specifically includes: environmental protection, environmental protection, pollution, energy consumption, emission reduction, sewage discharge, ecology, green, low carbon, air, chemical oxygen demand, sulfur dioxide, carbon dioxide, PM10, PM2.5 and etc. Different from the provincial government work report used by Chen Dengke et al. (2018), this paper further captures the importance attached by the prefecture level municipal government to environmental quality.

4. Analysis of Empirical Results

4.1 Benchmark Regression Result

According to the above-mentioned benchmark model, this part empirically examines the impact of environmental regulation on the green innovation level of heavy pollution enterprises. The benchmark regression results are shown in Table 2. Columns (1) and (2) of Table 2 report the fixed effect regression results, and columns (3) and (4) report the random effect regression results. In columns (1) and (3), only the core explanation and the explained variables are regressed, and the remaining control variables are introduced in columns (2) and (4).

Table 2. Benchmark regression results

VARIABLES	(1) invent	(2) invent	(3) invent	(4) invent
er	0.007**	0.010**	0.008**	0.014***
	(2.00)	(2.13)	(2.42)	(3.01)
rd		1.004***		1.481***
		(7.98)		(13.06)
ten		-0.011**		-0.002
		(-2.03)		(-0.48)
lev		-0.003		-0.003
		(-0.68)		(-0.76)
io		-0.001		0.000
		(-0.22)		(0.10)
roe		-0.002		-0.003
		(-0.63)		(-0.96)
growth		-0.001		-0.001
		(-0.75)		(-0.85)
Constant	0.363***	0.643	0.328**	-0.231
	(3.96)	(1.55)	(2.12)	(-0.57)
Observations	6,015	3,802	6,015	3,802
Number of i	670	602	670	602

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

According to the results listed in (1), environmental regulation has a positive impact on the level of green innovation of enterprises. The regression coefficient is 0.007, and the regression result is significant at the level of 5% significance. The regression result means that environmental regulation has significantly improved the level of green innovation of enterprises. The reason may be that when heavy polluting enterprises are faced with strict environmental regulation policies, they will actively

increase technological innovation activities in order to improve the production efficiency and competitiveness of enterprises. The conclusion of this paper supports the "Porter Hypothesis". After adding other control variables, the regression results are still significant at the 5% significance level, indicating that the conclusion of this paper is robust. The regression results using random effects are also positive, indicating that environmental regulation has a significant role in promoting the level of green innovation of enterprises.

4.2 Robustness Test Results

Table 3 further reports the robustness test results using the sum of green invention patents and green utility model patents. Columns (1) and (2) of Table 3 report the fixed effect regression results, while columns (3) and (4) report the random effect regression results; In columns (1) and (3), only the core explanation and the explained variables are regressed, and the remaining control variables are introduced in columns (2) and (4).

According to the results listed in (1), environmental regulation has a positive impact on the level of green innovation of enterprises. After adding other control variables, the regression result is still significant at the level of 5%, indicating that the conclusion of this paper is robust. The regression results using random effects are also positive, indicating that environmental regulation has a significant role in promoting the level of green innovation of enterprises.

Table 3. Robustness test results using the sum of green invention patents and green utility model patents

VARIABLES	(1) Pinvent	(2) Pinvent	(3) Pinvent	(4) Pinvent
er	0.007	0.017**	0.008	0.022***
	(1.12)	(2.15)	(1.41)	(2.81)
rd		1.755***		2.445***
		(8.46)		(12.42)
ten		-0.013		0.000
		(-1.45)		(0.05)
lev		0.008		0.009
		(1.10)		(1.33)
io		-0.000		-0.000
		(-0.09)		(-0.04)
roe		0.000		-0.000
		(0.08)		(-0.10)
growth		-0.001		-0.001
		(-0.82)		(-0.90)
Constant	1.319***	0.889	1.274***	-0.411
	(8.39)	(1.30)	(3.92)	(-0.56)
Observations	6,015	3,802	6,015	3,802
Number of i	670	602	670	602

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4 reports the robustness test results of the frequency ratio of environmental protection words. Columns (1) and (2) of Table 4 report the fixed effect regression results, while columns (3) and (4) report the random effect regression results; In columns (1) and (3), only the core explanation and the explained variables are regressed, and the remaining control variables are introduced in columns (2) and (4).

According to the results of (1) and (2), before and after adding other control variables, environmental regulation has a positive impact on the green innovation level of enterprises, which indicates that the conclusion of this paper is robust. The symbols of the regression results using random effects are also positive, and the regression coefficients are significant at 10% and 5% significance levels before and after the control variables are added, indicating that environmental regulation has a significant role in promoting the level of green innovation of enterprises.

Table 4. Robustness test results of frequency proportion of environmental protection words

VARIABLES	(1) invent	(2) invent	(3) invent	(4) invent
per	0.376	0.454	0.462*	0.769**
	(1.45)	(1.28)	(1.80)	(2.21)
rd		0.998***		1.479***
		(7.91)		(13.01)
ten		-0.011**		-0.002
		(-1.98)		(-0.41)
lev		-0.003		-0.003
		(-0.74)		(-0.80)
io		-0.001		0.000
		(-0.23)		(0.09)
roe		-0.002		-0.002
		(-0.61)		(-0.93)
growth		-0.001		-0.001
		(-0.77)		(-0.86)
Constant	0.399***	0.730*	0.366**	-0.171
	(3.99)	(1.73)	(2.29)	(-0.42)
Observations	6,015	3,802	6,015	3,802
Number of i	670	602	670	602

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Referring to Liu Yunguo et al. (2016), Table 5 reports the robustness test results of replacing samples of heavily polluting enterprises.

According to the results listed in (1), environmental regulation has a positive impact on the level of green innovation of enterprises, and the regression result is significant at the 10% significance level. After adding other control variables, the significance of the regression results is improved, and the regression coefficient is significant at the significance level of 5%, indicating that the conclusion of this paper is robust. The regression results using random effects are also positive, indicating that environmental regulation has a significant role in promoting the level of green innovation of enterprises. The research conclusion supports the “Porter Hypothesis”.

Table 5. Robustness test results of replacing heavily polluted enterprise samples

VARIABLES	(1) invent	(2) invent	(3) invent	(4) invent
er	0.007*	0.011**	0.008**	0.015***
	(1.72)	(2.02)	(2.06)	(2.79)
rd		1.090***		1.598***
		(7.70)		(12.57)
ten		-0.012**		-0.004
		(-2.00)		(-0.63)
lev		-0.004		-0.004
		(-0.82)		(-1.03)
io		-0.000		0.001
		(-0.12)		(0.38)
roe		-0.002		-0.003
		(-0.67)		(-1.04)
growth		-0.001		-0.001
		(-0.57)		(-0.65)
Constant	0.397***	0.727	0.365**	-0.189
	(3.87)	(1.55)	(2.09)	(-0.42)
Observations	5,250	3,292	5,250	3,292
Number of i	585	525	585	525

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.3 Further Discussion Result

To investigate the regulatory effect of property rights on the relationship between environmental regulation and enterprise green innovation level, Table 6 reports the group regression results of environmental regulation. According to the results of (1) and (3), the positive impact of environmental regulation on the level of green innovation of enterprises is only significant in the non-state-owned enterprises, but not in the state-owned enterprises; According to the regression results using random effects in columns (2) and (4), the significance of the regression coefficient has not changed, indicating that the conclusion of this paper is robust. The regression conclusion shows that environmental regulation has a more significant role in promoting the green innovation level of non-state-owned enterprises.

Table 6. Grouping regression results of green invention patents

	(1)	(2)	(3)	(4)
	Non-state enterprise		State enterprise	
VARIABLES	invent	invent	invent	invent
er	0.015**	0.019***	0.002	0.006
	(2.55)	(3.41)	(0.31)	(0.75)
rd	1.428***	1.800***	0.549***	0.899***
	(7.72)	(12.53)	(3.28)	(5.56)
ten	-0.009	-0.003	-0.006	0.002
	(-1.36)	(-0.62)	(-0.61)	(0.20)
lev	-0.004	0.000	-0.003	-0.003
	(-0.80)	(0.05)	(-0.45)	(-0.46)
io	-0.003	-0.002	0.003	0.004
	(-0.77)	(-0.64)	(0.67)	(0.90)
roe	-0.001	-0.001	-0.003	-0.003
	(-0.42)	(-0.44)	(-0.76)	(-0.86)
growth	-0.000	-0.000	-0.001	-0.001
	(-0.48)	(-0.37)	(-0.59)	(-0.76)
Constant	0.231	-0.606	0.801	0.066
	(0.46)	(-1.48)	(1.04)	(0.08)
Observations	2,479	2,479	1,323	1,323
Number of i	401	401	201	201

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Policy Recommendation

Based on the sample data of Shanghai and Shenzhen A-share listed companies in the heavy pollution industry from 2012 to 2021, this paper empirically examines the impact of environmental regulation on the level of green innovation of enterprises by using the frequency of environmental protection words in the work reports of prefecture level municipal governments as the proxy variable of environmental regulation. This study finds that government regulation significantly improves the level of green innovation of enterprises, supporting the “Porter Hypothesis”, and the promotion effect is more significant for non-state enterprises.

Based on the above conclusions, this paper draws the following policy recommendations:

(1) Flexibly use diversified environmental regulation tools.

The government should flexibly adopt diversified environmental regulation tools, promote the cooperation between different environmental regulation tools, give play to the power of the government, enterprises and the public, and build a diversified environmental regulation system to promote the improvement of the level of green technology innovation in China. Different environmental regulation tools are applicable to different regions. Command control regulatory tools are mandatory and applicable to areas with weak environmental supervision. Market incentive regulation tools are suitable for regions with sound market systems. Voluntary regulatory tools are

suitable for areas with high public awareness of environmental protection and environmental management ability.

(2) Establish a reasonable enforcement intensity of environmental regulations.

The intensity of environmental regulation should be selected according to the actual situation, and economic and environmental benefits should be comprehensively considered. If the government wants to protect the areas with relatively backward production capacity, promote regional economic development and solve the problems of local labor employment, it can set a relatively low regulatory intensity. When the regional economy develops well and the local government pays more attention to environmental protection objectives, a relatively high regulatory intensity should be set. By formulating reasonable environmental regulation intensity, the government can not only effectively guide enterprises to carry out green innovation, but also avoid excessive burden on enterprises and achieve a win-win situation between environmental protection and regional economic development.

(3) Formulate differentiated environmental regulation policies for enterprises of different ownership types.

When designing environmental regulation policies, the government should fully consider the impact of different ownership types on enterprises and implement targeted regulation policies to enable enterprises to carry out green innovation under appropriate policy pressure. Compared with non-state enterprises, state enterprises have lower green technology innovation ability and higher tolerance to environmental regulation. Therefore, the binding force of environmental regulation has a weak impact on state enterprises. The government should increase the weight of environmental protection performance in the performance assessment of state enterprises, formulate more strict environmental regulation implementation standards, improve the environmental regulation supervision system, strengthen the punishment of enterprises for violations and enhance the motivation of state enterprises to carry out green innovation. The government should also give greater support to non-state enterprises for green innovation and guide non-state enterprises to increase their R&D investment in green innovation technology through talent introduction, financial subsidies, financing support, etc., so as to improve the green innovation ability of non-state-owned enterprises.

(4) Strengthen the environmental protection responsibilities of enterprises and encourage them to carry out green innovation.

Strengthening green technology innovation has become an important means to improve the quality of economic development and change the mode of economic development. As an important participant in China's green development strategy, enterprises should establish a sense of environmental protection responsibility and actively carry out green technology innovation and research activities. The government should improve relevant environmental protection laws and regulations and environmental responsibility disclosure system, implement differentiated supervision strategies for different types of enterprises, urge enterprises to install pollution source monitoring facilities, carry out self-discipline supervision, actively disclose relevant information and enhance the environmental awareness of enterprises. At the same time, enterprises need to formulate a reasonable green innovation development strategy, increase investment in research and development of green innovation technologies, make full use of environmental subsidies and other resources provided by the government, and maximize the green innovation performance of enterprises.

References

[1] Brunnermeier, S. B., M. A. Cohen. Determinants of environmental innovation in US manufacturing industries[J]. Journal of Environmental Economics and Management. Vol. 45 (2003) No. 2.

[2] Chen, S. Y., D. K. Chen. Haze pollution, government governance and high-quality economic development[J]. Economic Research. Vol. 53 (2018) No. 02, p. 20-34.

[3] Chintrakarn, P. Environmental regulation and U.S. states' technical inefficiency[J]. Economics Letters. Vol. 100 (2008) No. 3.

[4] Du, L. Z., Y. H. Zhao, K. T. Tao, et al. The compound effect of environmental regulation and governance transformation on Green Competitiveness Improvement--Based on the empirical evidence of Chinese industry[J]. Economic Research. Vol. 54 (2019) No. 10, p. 106-120.

[5] Frondel, M., J. Horbach, K. Rennings. End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries[J]. Business Strategy & the Environment. Vol. 16 (2007) No. 8, p. 571–584.

[6] Gao, W., J. H. Cheng, J. Zhang. Influence of heterogeneous environmental regulation on green development of mining industry[J]. China Population, Resources and Environment. Vol. 28 (2018) No. 11, p. 150-161.

[7] Gray, W. B., R. J. Shadbegian. Plant vintage, technology, and environmental regulation[J]. Journal of Environmental Economics and Management. Vol. 46 (2003) No. 3.

[8] Jin, G., K. R. Shen. Beggar thy neighbor or keep thy neighbor company--Interaction of environmental regulation enforcement and urban productivity growth[J]. Management World. Vol. 34 (2018) No. 12, p. 43-55.

[9] Jing, W. M., L. Zhang. Environmental regulation, opening up and green technology progress of Chinese industry[J]. Economic Research. Vol. 49 (2014) No. 09, p. 34-47.

[10] Li, B., X. Peng, M. K. Ouyang. Environmental regulation, green total factor productivity and the transformation of China's industrial development mode--An Empirical Study Based on the data of 36 industrial industries[J]. China Industrial Economy. (2013) No. 04, p. 56-68.

[11] Li, L., F. Tao. The choice of optimal environmental regulation intensity of China's manufacturing industry--From the perspective of green total factor productivity[J]. China Industrial Economy. (2012) No. 05, p. 70-82.

[12] Li, Q. Y., Z. H. Xiao. Heterogeneous environmental regulation tools and enterprise green innovation incentives--Evidence from green patents of listed enterprises[J]. Economic Research. Vol. 55 (2020) No. 09, p. 192-208.

[13] Liu, J. K., Y. Y. Xiao. China's environmental protection tax and green innovation: leverage effect or crowding out effect? [J]. Economic Research. Vol. 57 (2022) No. 01, p. 72-88.

[14] Liu, Y. G, M. N. Liu. Does haze affect the earnings management of heavily polluting enterprises--Investigation based on political cost hypothesis[J]. Accounting Research. (2015) No. 03, p. 26-33 + 94.

[15] Luo, D. L., Z. H. Lai. Investment in heavy pollution enterprises and promotion of local officials--Empirical Evidence Based on the data of prefecture level cities from 1999 to 2010[J]. Accounting Research. (2016) No. 04, p. 42-48 + 95.

[16] Palmer, K. L., W. E. Oates, P. R. Portney. Tightening environmental standards: the benefit-cost or the no-cost paradigm?[J]. Journal of Economic Perspectives. Vol. 9 (1995) No. 4.

[17] Pan, A.L., X. Liu, J. L. Qiu, et al. Can green M&A under media pressure promote the substantial transformation of heavy polluting enterprises[J]. China Industrial Economy. (2019) No. 02, p. 174-192.

[18] Porter, M. E. Americas green strategy[J]. Scientific American. Vol. 264 (1991) No. 4.

[19] Shen, N. Environmental efficiency, industry heterogeneity and optimal regulation intensity--Nonlinear test of panel data of China's industrial industry[J]. China Industrial Economy. (2012) No. 03, p. 56-68.

[20] Tao, F., J.Y. Zhao, H. Zhou. Does environmental regulation realize the "incremental improvement" of green technology innovation--Evidence from environmental protection target responsibility system[J]. China Industrial Economy. (2021) No. 02, p. 136-154.

[21] Wagner, M. On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms[J]. Research Policy. Vol. 36 (2007) No. 10.

[22] Wang, F.Z., X.C. Guo. Impact of environmental regulation intensity on green technology innovation of resource-based industries--An Empirical Test Based on panel data from 2003 to 2011[J]. China Population, Resources and Environment. (2015) No. S1, p. 143-146.

[23] Wang, X.Q., S. G. Hao, J.M. Zhang. New environmental protection law and green innovation of enterprises: forcing or squeezing? [J] China's Population, Resources and Environment. Vol. 30 (2020) No. 07, p. 107-117.

[24] Wang, X., X. Chu. Study on the same group effect of green technology innovation of manufacturing enterprises: reference function based on multi-level situation[J]. Nankai Management Review. (2021) No. 04, p. 1-24.

[25] Wu, L. B., F. Z. Ren, S. D. Xu. Impact of environmental regulation implementation on enterprise green innovation[J]. China Population, Resources and Environment. Vol. 31 (2021) No. 01, p. 90-99.

[26] Xie, M. H., J. Wang, D.M. Liu. Environmental regulation, technological innovation and business performance[J]. Nankai Management Review. Vol. 17 (2014) No. 06, p. 106-113.

[27] Yin, B. Q. Environmental regulation and green total factor productivity of China's manufacturing industry--An Empirical Study Based on the perspective of international vertical specialization[J]. China Population, Resources and Environment. Vol. 22 (2012) No. 12, p. 60-66.

[28] Yuan, J. Q., D.Y. Zhang. Research on the impact of environmental regulations on industrial green total factor productivity: perspectives on the changes in the allocation ratio of factors among different industries[J]. Sustainability. Vol. 13 (2021) No. 23.

[29] Zhu, Y. J., Y. L. Wu. The impact of environmental regulations on technology innovation of coastal areas--an empirical analysis based on China's coastal area data[J]. Scientific Journal of Humanities and Social Sciences. Vol. 4 (2022) No. 3.