Environmental Sciences Europe

RESEARCH

Open Access

Threshold effects of environmental regulation types on green investment by heavily polluting enterprises

Zhenhua Wang[1], Ning Wang[2*], Xingqiu Hu[1] and Hongpeng Wang[1]

Abstract

Background: In the stage of sustainable development, enterprises should not only focus on economic efficiency, but also on ecological protection, for which the governments of various countries has adopted various environmental regulation methods to promote green investment by enterprises. However, there are many types of environmental regulations, and the relationship between policy formulation and implementation effects is complicated. Heavily polluting enterprises as the main carrier of resource consumption and pollutant emissions is the main target of environmental regulation. Based on this, we took China's heavily polluting listed companies as examples to explore the impact of different types of environmental regulations on green investment in heavily polluting enterprises.

Results: In this paper, environmental regulations were divided into formal and informal types, of which formal environmental regulations (FER) were subdivided into command-control and market-incentive types. The empirical results showed that the relationship between command-control environmental regulations and green investment by heavily polluting enterprises presents an inverted "U" shape, and market-incentive environmental regulations first have no effect on and then promote green investment by heavily polluting enterprises. Besides, informal environmental regulations (IER) have maintained a positive effect on green investment by heavily polluting enterprises.

Conclusions: Heavily polluting enterprises, respectively, employ passive, active and voluntary green investment strategies under the three types of environmental regulations, providing a reference for the government to promote green investment by enterprises by environmental regulations more effectively.

Keywords: Formal environmental regulation, Informal environmental regulation, Green investment, Heavily polluting enterprises

Introduction

Economic development and ecological protection have always been the major themes concerning the development of human civilization, and the synergetic development of economic growth and ecological balance is the core of long-term human progress [1]. China's industrialization level has been improved significantly since the reform and opening up, driving the economic development into a stage of rapid growth [2], while China's traditional industrial development is characterized by high energy consumption, heavy pollution and excessive resource dependence due to a lack of environmental awareness [3]. Rough economic growth has caused serious environmental pollution, which not only greatly affects human living environment and ecological balance, but also goes against the green and sustainable development emphasized nowadays. According to the *2020 Global Environmental Performance Index* jointly released by Yale University, Columbia University and the World Economic Forum, China ranks 120th out of 180 economies surveyed, while the top five are all European

*Correspondence: 1012272708@qq.com
[2] Business School of Jiangsu Normal University Kewen College, Xuzhou 221000, China
Full list of author information is available at the end of the article

Springer Open

© The Author(s) 2022. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

countries. The ranking indicates that China is facing enormous environmental pressure with its rapid economic development, and that there is a big gap between China and European countries in terms of environmental management. Therefore, Chinese governments at all levels have adopted a variety of environmental regulations to alleviate the contradiction between economic growth and ecological pollution. For example, a large number of environmental regulation policies have been enacted to force enterprises in order to innovate the production modes and reduce pollution emissions from the legal level [4]. Moreover, the Chinese government has leveraged the power of the public to strengthen environmental protection. China's latest *Environmental Protection Law* specifies that the public has access to environmental information, participation and supervision, and has the right to report to government departments through online channels and offline letters if they find any unit or individual polluting the environment or damaging the ecology [5]. It has been proposed in the report to the 19th National Congress of the Communist Party of China to implement an eco-environmental protection system and reform the eco-environmental regulatory system, which fully embodies the role of policy systems and supervision mechanisms in promoting green production in enterprises.

Heavily polluting enterprises as the main carrier of resource consumption and pollutant emissions is the main target of environmental regulation. Driven by the dual environmental regulation instruments of policy and public supervision, heavily polluting enterprises change their production processes and reduce environmental pollution by means of green investments (GI). Existing studies have also proved that environmental regulations can reduce the pollution emissions of enterprises by promoting enterprise technological upgrading [6] and adjusting industrial structure [7]. There is often a complex nonlinear relationship between policy development and implementation results, not only will also be affected by the policymakers, implementers, but also affected by environmental regulation degree. Overly stringent environmental regulations may have significant adverse effects on business operation and are detrimental to the GI of enterprises [8], while unduly lenient environmental regulations may also make it difficult to restrict the pollution emissions by enterprises [9]. At the same time, there are many forms in environmental regulations, which may also have different degrees of impact on corporate GI.

On this basis, environmental regulations were classified into three categories in this paper, and the effects of different types of environmental regulations on promoting GI by heavily polluting enterprises were explored, so as to (1) verify the promotion degree of different environmental regulations to GI by heavily polluting enterprises; (2) determine the optimal promotion degree of environmental regulations to GI by heavily polluting enterprises and seek the best balance among the promotion degree of environmental regulations, GI by enterprises and enterprise benefits; (3) and to provide practical references for government departments and heavily polluting enterprises to make better use of environmental regulation tools and promote the achievement of the synergetic development of economic growth and ecological balance in China.

Literature review

Types of environmental regulations

Environmental regulations have been explored for a long period of time in academic circles, Chai and Sun [10] described the concept of environmental regulation as a binding force with environmental protection as the objective, individuals or social organizations as the objects, and tangible institutions or intangible consciousness as the existence form. Scholars have subdivided the types of environmental regulations on account of the richness of the subjects included in environmental regulations, including: (1) formal and informal environmental regulations based on different subjects of regulations [11, 12], where formal environmental regulations (FER), starting from the government and related institutions, intervene in the behaviors of market entities by formulating laws and policies [13], while informal environmental regulations (IER) refer to the reduction of environmental damage caused by market entities through supervision, protests, and complaints by social groups or individuals [14]. Pan et al. [15] and Dai et al. [16] classified FER into command-control and market-incentive types, which is also the main classification method of environmental regulations by current scholars, e.g., Li and Wang [17]. (2) Based on the investment concept, Han [18] and Zhang [19] regarded environmental regulation as a kind of economic input and classified it into cost-based and investment-based environmental regulations. The basis is the fact that environmental regulations will not only increase the costs associated with environmental protection such as sewage charges and regulatory fees, but also promote GI by enterprises and advance production technologies, which will have a positive effect on improving enterprise images and competitiveness.

Effects of environmental regulations on enterprise development

There are two views about the impact of environmental regulations on enterprise development. First, the "compliance cost theory", it describes the costs of bearing environmental damage should follow the Polluter Pays

Principle (PPP), those who "cause pollution" should pay for the harm they inflict on others, for example in the form of taxes, emission allowances or command and control measures [20]. Thus environmental regulations will increase enterprises' investment in green technologies and pollution control costs, resulting in increased production costs [21] and reduced production efficiency [22]. Second, the "innovation compensation theory", the Porter hypothesis suggests that well-designed regulation can improve the competitiveness of enterprises [23]. Reasonable environmental regulations only increase the cost input of enterprises in a short period of time, diverting R&D input and inhibiting patent output. However, in the long run, reasonable environmental regulations can improve technological progress and energy efficiency, facilitate industrial transformation and upgrading, and at the same time, these inputs reflect the positive response of enterprises to policies, enabling enterprises to enjoy more policy dividends and enhance their long-term development capacities [24, 25].

Effects of environmental regulations on enterprise GI

The impact of environmental regulations on GI has not attracted enough attention from scholars. Generally speaking, GI will increase the cost pressure of enterprises, so it is difficult for enterprises to actively increase GI. Through empirical research, scholars have come to the conclusion that environmental regulations can promote GI of enterprises: as environmental regulations are strengthened, enterprises will "passively" increase GI. Han et al. pointed out that green investment is a positive response to the concept of ecological civilization, and environmental regulations have promoted corporate green investment from a legal and cultural perspective [26]. Liao believes that public appeals as informal environmental regulations can also increase the government's strength to environmental supervision, which can promote GI in enterprises [27].

An overview of the current national and international studies can lead to the following conclusions: (1) environmental regulations have a significant impact on economic and enterprises development, but the impact of environmental regulations on enterprises GI has not attracted enough attention. Environmental regulations are of various types, and the effects of different types of environmental regulations on enterprises GI may be different. (2) The main role of environmental regulations is to reduce pollutant emissions from enterprises by formal and informal means. Heavily polluting enterprises are emitting a large amount of pollutants, causing great environmental pressure, and are the main target of environmental regulation. According to the PPP, those who "cause pollution" should take control measures to reduce it. Thus studying the impact of environmental regulations on GI by heavily polluting enterprises may achieve a more effective and targeted improvement of the ecological environment. (3) The current research focuses on the linear relationship between environmental regulation and enterprises GI, but the relationship between policy development and implementation effect is complex. Exploring the nonlinear relationship between different environmental regulation types and heavy pollution enterprises GI to find a suitable environmental regulatory tool is more valuable.

Selection of variables

This study aims to investigate the nonlinear effects of environmental regulation types on GI by heavily polluting enterprises. To achieve the study purpose, the data of listed companies among heavily polluting enterprises in China during 2010–2018 were selected as samples to study the impact of environmental regulations on corporate GI. Environmental regulations were divided into formal and informal types according to the current study results, and FER was further divided into command-control and market-incentive types. Command-control environmental regulations (CCR) refer to the condition that the government forces heavily polluting enterprises to make GI by directly enacting environmental regulations. Market-incentive environmental regulations (MIR) refer to indirect allocation of resources through the market, in order to promote heavily polluting enterprises to increase GI. For example, the increase of environmental protection input and investment in pollution control facilities by the government is an effective tool of MIR. IER indicates a method to promote GI through public and organizational supervision to the production processes of enterprises.

(1) Dependent variables: GI. The indicators were quantified based on the corporate environmental information disclosed in the corporate environmental report. Corporate GI was quantified by most scholars based on the amount of environmental investments disclosed by enterprises, but there are errors in the resulting conclusions because the presence of a time lag will make the results not objective enough. Therefore, corporate GI was measured in this paper by establishing corporate GI indicators, where various types of environmental information disclosed by enterprises were quantified through objective scoring. Content analysis method has been fully applied in the existing literature to study corporate social responsibilities. Zeca et al. [28] constructed evaluation indicators from three aspects of economic benefit, environmental benefit and social benefit to assess the value of corporate GI. In this paper, the level of corporate GI was measured with reference to the method of Zheng [29], and an evaluation indicator system was

established (Table 1). Corporate GI was mainly divided into five categories, including comprehensive management investment, pollution control investment, resource-saving investment, climate change response investment and environmental protection related investment, and then scored using 15 secondary indicators, with a score range of 0–3 points. Wherein, 0 indicates no disclosure, 1 stands for qualitative description, 2 represents quantitative description, and 3 refers to both qualitative and quantitative description.

(2) Independent variable: types of environmental regulations

① FER

The method of measuring FER indicators draws on Cheng's et al. studies [30]. The intensity of CCR was measured using the number of environmental regulations enacted each year in the province where the sample enterprises were located. The intensity of MIR was measured by the ratio of the investment amount in environmental management in the province where the sample enterprises were located to the GDP of that province.

② IER

IER refers to the condition that the public and organizations spontaneously participate in relevant activities aimed at environmental protection, energy conservation and emission reduction. Given the availability of data, the IER was measured in this paper using the ratio of petition batches to the total population in the province where the sample enterprise was located by the method of Gao and Chen [31].

(3) Controlled variable

① Cash flow (CF)

According to the findings of existing literature, it can be found that the higher the CF of enterprises, the more willing they are to invest in more projects [32]. In other words, an enterprise will be more willing to make GI in the case of sufficient CF. As a result, it can be concluded that the higher the CF of enterprises, the larger the scale of GI.

② Financial leverage (FL)

The FL level of a company affects the GI decision [33]. High financial leverage ratios of an enterprise indicate large debts. Hence, the creditor may change the interest rate according to the time the enterprise delays the debt, which in turn will increase the cost of the enterprise, i.e., the debtor, and then the enterprise will reduce the GI level moderately.

③ Return on assets (ROA)

When the ROA of an enterprise is high, the value of the enterprise will increase [34], and the internal production pressure of the enterprise will be reduced moderately. At that time, the enterprise will pay more attention to the long-term development strategy, as well as its reputation in the market, rather than the momentary return during decision-making. Therefore, the higher the profitability of enterprises, the more it can promote the scale of GI.

④ Investment opportunities (IO)

Enterprises will increase their investment to enter some emerging industries when the Tobin's Q value is high [35], so all kinds of investment opportunities are very valuable for developing enterprises. GI is one of the ways for enterprises to make technology replacement and gain competitive advantages in the market, so enterprises are more willing to make GI in the face of greater investment opportunities.

Table 1 Corporate GI evaluation indicator system

Primary indicators	Secondary indicators
Comprehensive management investment	Total investment
Pollution control investment	Pollution and waste identification
	Source measurement, recording and reporting
	Pollution control measures
	Source identification
Resource-saving investment	Search of feasible opportunities
	Resource usage measurement, recording and reporting
	Emission reduction measures
Climate change response investment	Identification of emission sources Emission measurement and reporting Emission reduction measures Changes in production and business processes
Environmental protection related investment	Green technology innovation Development and implementation of environmental regulations Collection and collation of environmental disclosure information

⑤ Cash holdings (CH)

In the case of sufficient CF, enterprises face low business pressure and will be more inclined to invest cash in various projects, and enterprises with high CH are more advantageous in terms of investment opportunities and risks compared with enterprises with low CH [36]. Consequently, enterprises with high CH will also have high levels of GI.

With the increasingly strengthened environmental regulations, heavily polluting enterprises have paid more and more attention to the disclosure of GI-related data, which has ensured the integrity of their GI data in recent years. In this paper, all data were obtained from the China Stock Market & Accounting Research Database (CSMAR) and the annual reports of heavily polluting enterprises, excluding enterprises with missing data and enterprises under Special Treatment (ST). Table 2 demonstrates the statistical description of the variables selected for this study.

Modeling

The panel threshold model proposed by Hansen was examined in this study. By virtue of the model, slice functions could be constructed based on changes in the threshold of variables, so as to analyze the relationship and degree of influence between variables [37]. The basic equation of this model is shown in Formula (1):

$$Y_{it} = \mu_i + \beta_1^{'} x_{it} I(q_{it} \le \gamma) + \beta_2^{'} x_{it} I(q_{it} > \gamma) + e_{it}. \tag{1}$$

According to the variables and measurements selected in this paper, the definition of each code in this model is listed in Table 3.

In Formula (1), the indicator function will be assigned a value of 1 when the conditions in the parentheses are met; otherwise it will be assigned a value of 0. Formula (1) could be adjusted accordingly as follows:

Table 2 Statistical description

Variable	Mean	Std. Dev	Min	Max
GI	17.871	1.978	11.915	22.807
CCR	14.773	1.338	12.386	17.18
MIR	20.649	1.765	14.437	23.9
IER	1.483	0.761	0.4	4.03
FL	0.649	0.449	0.131	4.783
ROA	0.025	0.106	-0.683	0.765
CF	0.064	0.108	-0.204	1.084
IO	1.694	1.449	0.176	7.987
CH	0.064	0.203	-0.203	0.283

Table 3 Code definition

Code	Definition
i	Heavily polluting enterprises
t	Year
Y_{it}	Dependent variable
x_{it}	Independent variable
q_{it}	Threshold variable
γ	Threshold value to be estimated
e_{it}	Random disturbance item
$\beta_1^{'}, \beta_2^{'}$	Coefficient to be estimated
μ_i	Remove individual-specific means
$I(.)$	Indicator function

$$Y_{it} = \begin{cases} \mu_i + \beta_0^{'} z_{it} + \beta_1^{'} x_{it} + e_{it}, q_{it} \le \gamma \\ \mu_i + \beta_0^{'} z_{it} + \beta_2^{'} x_{it} + e_{it}, q_{it} > \gamma \end{cases}. \tag{2}$$

z_{it} refers to the controlled variables, including CF, FL, ROA, IO and Cash in this study. The sum of squared errors was obtained according to the Hansen panel threshold regression model, as shown in Formula (3):

$$\begin{aligned} S_1(\gamma) &= \hat{e}^*(\gamma)^{'} \hat{e}^*(\gamma) \\ &= Y^{*'}(1 - x^*(\gamma)^{'}(x^*(\gamma)^{'} x^*(\gamma))^{-1} x^*(\gamma)^{'}) Y^*, \end{aligned} \tag{3}$$

wherein $x_{it}(\gamma) = \begin{pmatrix} x_{it} I(q \le \gamma) \\ x_{it} I(q\gamma) \end{pmatrix}$; $Y_{it}^* = Y_{it} - \bar{Y}_{it}$; $e_{it}^* = e_{it} - \bar{e}_{it}$; $x_{it}^* = x_{it} - \bar{x}_{it}$; $\hat{\beta}(\gamma) = (x^*(\gamma)^{'} x^*(\gamma))^{-1} x^*(\gamma)^{'} Y^*$; $\hat{e}^*(\gamma) = Y^* - x^*(\gamma)\hat{\beta}^*(\gamma)$.

Moreover, γ could be calculated by the least squares method and Formula (3). The least squares estimate is shown in Formula (4):

$$\hat{\gamma} = \arg\min_{\gamma} S_1(\gamma). \tag{4}$$

After determining the value of $\hat{\gamma}$, the residuals were calculated as shown in Formula (5):

$$\hat{\sigma}^2 = \frac{1}{n(T-1)} \hat{e}^{*'} \hat{e}^* = \frac{1}{n(T-1)} S_1(\hat{\gamma}). \tag{5}$$

In this study, according to the above threshold regression model and the selected variables, Formula (1) was rewritten. The single-threshold model is shown in Formula (6), and a multi-threshold model was derived based on the double-threshold model, as shown in Formula (7):

$$\begin{aligned} Y_{it} &= \mu_i + \beta\prime_0 z_{it} + \beta\prime_1 new_{it} I(q_{it} \le \gamma_1) \\ &\quad + \beta\prime_2 new_{it} I(q_{it}\gamma_1) + e_{it}, \end{aligned} \tag{6}$$

$$Y_{it} = \mu_i + \beta_0^{'} z_{it} + \beta_1^{'} new_{it} I(q_{it} \le \gamma_1) + \beta_2^{'} new_{it} I(\gamma_1 < q_{it} \le \gamma_2) + \beta_3^{'} new_{it} I(q_{it} > \gamma_2) + e_{it}. \quad (7)$$

Empirical analysis

Hansen presented the panel threshold model based on fixed effects, and it was necessary to test whether the fixed effects held by Hausman test when using panel threshold regression. Since the null hypothesis of coefficient differences was not systematically rejected by the results of Hausman test in Table 4, the fixed effect held.

In general, if the panel data slope is homogeneous, the slope coefficient of the panel data remains constant across individuals. Hence, the panel data need to pass the cross-sectional dependence (CSD) test prior to the establishment of the panel threshold model. The CSD test includes three types of statistics programs of Pesaran's cross-sectional dependence test, the Friedman statistic, and the test statistic proposed by Frees.

The results in Table 4 shows that both the Pesaran test and Friedman test rejected the null hypothesis of the existence of cross-sectional independence. Moreover, the average absolute values of all off-diagonal elements were greater than 0, indicating that there is no error in the CSD test where the sum of the positive and negative correlations was 0. Meanwhile, the statistical value of Frees test was greater than the critical value of Alpha = 0.01. The CSD test above confirmed the homogeneity in cross-sectional slopes of panel data.

Based on the above tests, it was concluded that a stability threshold regression model could be constructed. In this paper, by the Bootstrap method, specific threshold values were obtained by repeatedly sampling the threshold variables for 300 times. The calculated outcomes of the obtained threshold values are presented in Table 5.

Table 4 Hausman test

Chi2(4)	Prob > Chi2	Null hypothesis
19.51	0.000	Rejected

Table 6 Threshold values

Threshold variables	Threshold effects	F-statistics	P-values	Threshold values
CCR	Single threshold	32.17***	0.000	2.53
	Double threshold	5.42	0.542	
MIR	Single threshold	29.42***	0.000	27.18
	Double threshold	6.21	0.413	
IER	Single threshold	3.24	0.713	
	Double threshold	9.32	0.832	

The results in Table 6 illustrate that there is a threshold value of 1 for the two kinds of threshold regression models when CCR and MIR were used as the threshold variables. The threshold value was 2.53 for CCR and 27.18 for MIR. There is no threshold value when IER was used as a threshold variable.

Note: ***, **, and * denote that the regression outcomes are significant at 1%, 5%, and 10%.

In this study, the impact of the types of environmental regulations on GI by heavily polluting enterprises was analyzed by virtue of the threshold regression model, and the results are shown in Table 7. Models 1, 2 and 3 represent threshold regressions with CCR, MIR, and IER as threshold variables, respectively.

According to the threshold regression results of Models 1, 2 and 3, environmental regulations affect the degree of GI by heavily polluting enterprises, and the effect of environmental regulations varies significantly by type.

In Model 1, the regression coefficient of GI was 1.534 when the CCR was less than or equal to 2.53, which passed the significance test, suggesting that CCR significantly promotes GI by heavily polluting enterprises. However, when the CCR was greater than 2.53, the regression coefficient of GI was -0.169, which indicated that the CCR has a negative impact on the GI by heavily polluting enterprises. The empirical results of Model 1 demonstrated that the effects of CCR on GI by heavily polluting enterprises vary with the strict degree of environmental regulations, and CCR significantly promotes GI by heavily polluting enterprises within a certain extent, but the promotion will turn into inhibition when it exceeds a certain extent.

Table 5 CSD test

	Pesaran test	Friedman test
Test of cross-sectional independence	2.452*** (0.009)	25.140*** (0.002)
Average absolute value of the off-diagonal elements	0.286	0.224
Frees' test = 0.513		
Alpha = 0.10: 0.1612	Alpha = 0.05: 0.2371	Alpha = 0.01: 0.3502

Table 7 Threshold regression results

Model 1		Model 2		Model 3	
Variable	**Single threshold model**	**Variable**	**Single threshold model**	**Variable**	**Fixed effect**
CCR (CCR ≤ 2.53)	1.534***	MIR (MIR ≤ 27.18)	0.073**	IER	0.313***
CCR (CCR > 2.53)	−0.169***	MIR (MIR > 27.18)	1.313**		
IO	0.056**	IO	0.054**	IO	0.027*
FL	0.012*	FL	0.007*	FL	−0.122
ROA	0.064*	ROA	0.032*	ROA	0.068
CH	0.003	Cash	0.003	Cash	0.002*
CF	0.011	CF	0.014**	CF	0.071*
Cons	0.715***	Cons	0.657***	Cons	
R^2(within)	0.233	R^2(within)	0.273	R^2(within)	

***, **, and * denote that the regression outcomes are significant at 1%, 5%, and 10%

In Model 2, the regression coefficient of GI was 0.073 when the MIR was less than or equal to 27.18, indicating that the MIR fails to have a significant effect on GI by heavily polluting enterprises. However, when the MIR was greater than 27.18, the regression coefficient of GI rose to 1.313 and passed the significance test, which proved that the MIR begins to promote GI by heavily polluting enterprises significantly then.

In Model 3, there was no threshold for the IER and the regression coefficient of GI was 0.313, which suggested that IER can continue to have a positive effect on GI by heavily polluting enterprises.

According to the results of Models 1, 2 and 3, CCR, MIR, and IER all affected GI by heavily polluting enterprises, but the conditions of effects differed a lot. CCR first promoted GI by heavily polluting enterprises but caused inhibition when reaching a certain level. MIR first did not have much impact on GI by heavily polluting enterprises, but it promoted GI by heavily polluting enterprises significantly when reaching a certain level. In addition, IER has maintained a positive effect on GI by heavily polluting enterprises.

Results and discussion

The findings of this paper suggested that environmental regulations do have an impact on GI by heavily polluting enterprises, which were supported by the conclusions of Wang et al. [38] and Liao [5]. In this paper, the effects of different types of environmental regulations on GI by heavily polluting enterprises were explored, and the main findings are as follows:

(1) The relationship between CCR and GI by heavily polluting enterprises presents an inverted "U" shape, similar to the findings of Wang and Shen [39]. Before the degree of CCR exceeds a certain value, it can promote GI by heavily polluting enterprises, but after exceeding a certain value, it will inhibit GI by heavily polluting enterprises.

The result indicates that heavily polluting enterprises adopt passive GI strategies under CCR. When the government adopts relaxed CCR, there will be no great investment pressure for heavily polluting enterprises, and the enterprises choose to appropriately increase GI in response to the call of the policy [40]. However, when the government chooses to impose harsh CCR, GI by heavily polluting enterprises will be discouraged. This is because too much GI are risky and long-period, and heavily polluting enterprise cannot afford it, so they abandon the investment to reduce production costs [41]. In addition, harsh CCR can put more pressure on business operations, so heavily polluting enterprises will shift their industries to areas with less stringent environmental regulations in order to reduce the policy pressure in the location of their industries, creating a pollution haven effect, which does not increase the GI by heavily polluting enterprises [42].

Therefore, it is important for government departments to adjust the policy intensity of CCR. In the current situation, harsh CCR cannot achieve the purpose of promoting enterprises' GI, but may reduce GI or cause the "pollution haven" effect due to the increased burden on enterprises. Nevertheless, too lax environmental regulations can hardly form constraints on heavily polluting enterprises and have few promotion effects on GI. In consequence, the government should establish a good communication mechanism with heavily polluting enterprises to keep abreast of the impact of CCR on enterprise GI, so as to adjust the intensity of CCR in time. Only

moderate CCR can maximize the GI by heavily polluting enterprises and achieve a win–win situation for both economic development and environmental protection.

(2) There are two stages in the relationship between MIR and GI by heavily polluting enterprises. Until a certain level of MIR is reached, it has no effect on GI by heavily polluting enterprises. Subsequently, when the degree of MIR reaches a certain level, it significantly promotes the GI by heavily polluting enterprises.

The result reveals that heavily polluting enterprises adopt proactive GI strategies under MIR, and MIR can only play a facilitating role once the "market signal" reaches a certain level. When the degree of MIR is at a low level, enterprises are unable to receive market signals and will not make GI. When the MIR signal reaches the intensity acceptable to enterprises, MIR enables enterprises to be more proactive in GI on the basis of respecting the spontaneous regulation of the market economy. At this time, GI is the investment behavior that enterprises take the initiative to choose after receiving market signals, and enterprises can choose cheaper and more efficient energy-saving technologies to reduce the production costs independently. Under the premise of respecting the market law, not only the market competitiveness is improved through technological innovation, but also the environmental burden of enterprises is reduced [43, 44]. In consequence, MIR will enable heavily polluting enterprises to make green technological innovations and enlarge the scale of GI voluntarily after weighing the costs and benefits, and enterprises will also decide whether to make GI according to the intensity of MIR.

In contrast to CCR, MIR allows enterprises to make more independent choices about whether to make GI. As long as the market signal reaches a certain level, it can significantly motivate heavily polluting enterprises to make GI without obstruction. Therefore, government departments can make full use of market incentive tools to enhance market signals by increasing the investment in environmental protection and improving the construction of pollution control facilities, so as to continuously enhance the promotion effect of MIR on GI by heavily polluting enterprises. It is also necessary for enterprises to strengthen market research and enhance the ability to obtain market signals and grasp market opportunities.

(3) IER has always had a positive and linear promotion effect on GI by heavily polluting enterprises, which is supported by the study of Zhang and Sun [45].

The result suggests that heavily polluting enterprises adopt voluntary GI strategies under IER. IER has a positive linear effect on GI by heavily polluting enterprises although no nonlinearity is detected, indicating that the public can take a variety of petitions, exposure and other diverse channels to supervise enterprises, especially heavily polluting enterprises with the enhancement of public awareness of environmental protection. Heavily polluting enterprises will voluntarily change their investment strategies and actively fulfill their social responsibilities to meet consumer demand and build corporate images [27, 46].

Therefore, IER originates from the environmental awareness of people and plays a linear positive role in GI by heavily polluting enterprises. Compared with FER, IER is more flexible and is not affected by the intensity of regulations and market signals. However, the current positive effect of IER on GI by heavily polluting enterprises is slightly smaller than that of MIR. It is necessary for the government to actively popularize environmental protection knowledge, publicize the importance of green production, and enhance the environmental awareness of the public and social organizations. Both the public and the social organizations should play a supervisory role over the heavily polluting enterprises and inspire the willingness of heavily polluting enterprises to increase GI voluntarily. Heavily polluting enterprises should take the initiative to establish the awareness of green development, actively accept public supervision and improve green production capacity.

Conclusions

In summary, different types of environmental regulations have different promotion effects on GI by heavily polluting enterprises. Currently, the most effective environmental regulation tool is MIR. IER also has a good promotion effect, so the government can enhance the promotion effect of IER on GI by heavily polluting enterprises by enhancing public awareness through publicity, education, and training. As for CCR, the government should pay particular attention to the intensity of environmental regulations and policies formulated, and the promotion effect on GI by heavily polluting enterprises can be maximized only in the appropriate intensity range. For heavily polluting enterprises, it is necessary for them to face the policy pressure of CCR and the social supervision pressure, improve market insight, and actively grasp market signals. On the one hand, enterprises should actively respond to the policy provisions, adjust the industrial structure, improve production technologies, and improve the green production capacity for long-term development. On the other hand, heavily polluting enterprises should actively assume social responsibilities, establish a green business philosophy, strengthen the publicity and education of green production, and improve corporate images, so as to contribute to ecological protection.

Abbreviations
CCR: Command-control environmental regulations; MIR: Market-incentive environmental regulations; FER: Formal environmental regulations; IER: Informal environmental regulations; GI: Green investment; CF: Cash flow; FL: Financial leverage; ROA: Return on assets; IO: Investment opportunities; CH: Cash holdings.

Acknowledgements
The authors would like to express their thanks to the Business School of HoHai University for their support in this work. Also we would like to thank the anonymous referees for their helpful suggestions and corrections on the draft of our paper.

Authors' contributions
All authors contributed to the study conception and design. Conceptualization and methodology: HW, XQ; data curation and writing—original draft preparation: ZW; writing—review and editing: NW. All authors read and approved the final manuscript.

Funding
This research was supported by the Fundamental Research Funds for the Central Universities (No. 2013-B210207026).

Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Business School of Hohai University, Nanjing 210000, China. [2]Business School of Jiangsu Normal University Kewen College, Xuzhou 221000, China.

Received: 5 January 2022 Accepted: 8 March 2022
Published online: 17 March 2022

References

1. Cumming GS, von Cramon-Taubadel S (2018) Linking economic growth pathways and environmental sustainability by understanding development as alternate social–ecological regimes. Proc Natl Acad Sci 115(38):9533–9538. https://doi.org/10.1073/pnas.1807026115
2. Wang Q, Su M (2019) The effects of urbanization and industrialization on decoupling economic growth from carbon emission–a case study of China. Sustain Cities Soc 51:101758. https://doi.org/10.1016/j.scs.2019.101758
3. Ma Y, Yan J, Sha J, He G, Song C, Fan S, Ke W (2018) Dynamic simulation of the atmospheric environment improved by a focus on clean energy utilization of resource-based cities in China. J Clean Prod 192:396–410. https://doi.org/10.1016/j.jclepro.2018.04.247
4. Chang YC, Wang N (2010) Environmental regulations and emissions trading in China. Energy Policy 38(7):3356–3364. https://doi.org/10.1016/j.enpol.2010.02.006
5. Liao X (2018) Public appeal, environmental regulation and green investment: evidence from China. Energy Policy 119:554–562. https://doi.org/10.1016/j.enpol.2018.05.020
6. Jaraite J, Kazukauskas A, Lundgren T (2014) The effects of climate policy on environmental expenditure and investment: evidence from Sweden. J Environ Econ Policy 3(2):148–166. https://doi.org/10.1080/21606544.2013.875948
7. Hou J, Teo TS, Zhou F, Lim MK, Chen H (2018) Does industrial green transformation successfully facilitate a decrease in carbon intensity in China? An environmental regulation perspective. J Clean Prod 184:1060–1071. https://doi.org/10.1016/j.jclepro.2018.02.311
8. Wang S, Li J, Zhao D (2018) Institutional pressures and environmental management practices: The moderating effects of environmental commitment and resource availability. Busin Strat Environ 27(1):52–69. https://doi.org/10.1002/bse.1983
9. Zhao X, Sun B (2016) The influence of Chinese environmental regulation on corporation innovation and competitiveness. J Clean Prod 112:1528–1536. https://doi.org/10.1016/j.jclepro.2015.05.029
10. Chai, R., & Sun, Y. (2020). Empirical study for influence of demand effect-based environmental planning on environmental protection industry development. Modelling of Some Pollutants in the Air, 21(6), 2100–2109. https://www.researchgate.net/profile/Violin-Raykov/publication/348002379_
11. Kathuria V (2007) Informal regulation of pollution in a developing country: evidence from India. Ecol Econ 63(2–3):403–417. https://doi.org/10.1016/j.ecolecon.2006.11.013
12. Li R, Ramanathan R (2018) Exploring the relationships between different types of environmental regulations and environmental performance: evidence from China. J Clean Prod 196:1329–1340. https://doi.org/10.1016/j.jclepro.2018.06.132
13. Ouyang X, Shao Q, Zhu X, He Q, Xiang C, Wei G (2019) Environmental regulation, economic growth and air pollution: panel threshold analysis for OECD countries. Sci Total Environ 657:234–241. https://doi.org/10.1016/j.scitotenv.2018.12.056
14. Xiong B, Wang R (2020) Effect of environmental regulation on industrial solid waste pollution in china: from the perspective of formal environmental regulation and informal environmental regulation. Int J Environ Res Public Health 17(21):7798. https://doi.org/10.3390/ijerph17217798
15. Pan X, Ai B, Li C, Pan X, Yan Y (2019) Dynamic relationship among environmental regulation, technological innovation and energy efficiency based on large scale provincial panel data in China. Technol Forecast Soc Change 144:428–435. https://doi.org/10.1016/j.techfore.2017.12.012
16. Dai L, Mu X, Lee CC et al (2021) The impact of outward foreign direct investment on green innovation: the threshold effect of environmental regulation. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-12930-w
17. Li J, Wang C (2020) Impact of environmental regulation on industrial upgrading: analysis based on panel data of 30 provinces in China. Meteorol Environ Res 11(3):21–37. https://doi.org/10.19547/j.issn2152-3940.2020.03.005
18. Han SR, Li P, Xiang JJ, Luo XH, Chen CY (2020) Does the institutional environment influence corporate social responsibility? Consideration of green investment of enterprises—evidence from China. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-020-09559-6
19. Zhang Z (2021). Impact of Environmental Regulation on Industrial Green Efficiency——Based on Non-radial SBM Model. In Journal of Physics: Conference Series (Vol. 1744, No. 4, p. 042179). IOP Publishing. https://doi.org/10.1088/1742-6596/1744/4/042179
20. Schmidtchen D, Helstroffer J, Koboldt C (2021) Regulatory failure and the polluter pays principle: why regulatory impact assessment dominates the polluter pays principle. Environ Econ Policy Stud 23(1):109–144. https://doi.org/10.1007/s10018-020-00285-4
21. Palmer JK (1997) Environmental regulation and innovation: a panel data study. Rev Econ Stat 79(4):610–619. https://doi.org/10.2307/2951413
22. Chintrakarn P (2008) Environmental regulation and U.S. states' technical inefficiency. Econ Lett 100(3):363–365. https://doi.org/10.1016/j.econlet.2008.02.030
23. Ambec S, Cohen MA, Elgie S, Lanoie P (2020) The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? Rev Environ Econ Policy. https://doi.org/10.2139/ssrn.1754674
24. Yuan B, Xiang Q (2018) Environmental regulation, industrial innovation and green development of Chinese manufacturing: Based on an extended CDM model. J Clean Prod 176:895–908. https://doi.org/10.1016/j.jclepro.2017.12.034
25. Zhang G, Zhang P, Zhang ZG, Li J (2019) Impact of environmental regulations on industrial structure upgrading: an empirical study on

Beijing-Tianjin-Hebei region in China. J Clean Prod 238:117848. https://doi.org/10.1016/j.jclepro.2019.117848
26. Han Y (2020) Impact of environmental regulation policy on environmental regulation level: a quasi-natural experiment based on carbon emission trading pilot. Environ Sci Pollut Res 27(19):23602–23615. https://doi.org/10.1007/s11356-020-08658-8
27. Lončar D, Paunković J, Jovanović V, Krstić V (2019) Environmental and social responsibility of companies cross EU countries–Panel data analysis. Sci Total Environ 657:287–296. https://doi.org/10.1016/j.scitotenv.2018.11.482
28. Zeca ED, Stoica M, Bălănică CMD (2020) Indicators for Greening Value Chains. J Agroal Process Technol, 26(3), 155–159. https://www.journal-of-agroalimentary.ro/admin/articole/74426L26_
29. Zheng X (2019) The impact of environmental regulation on green investment. Harbin Univ Technol. https://doi.org/10.27061/d.cnki.ghgdu.2019.004725
30. Cheng Z, Li L, Liu J (2017) The emissions reduction effect and technical progress effect of environmental regulation policy tools. J Clean Prod 149:191–205. https://doi.org/10.1016/j.jclepro.2017.02.105
31. Gaoming CQ (2019) The influence of different types of environmental regulation on industrial upgrading. Industr Technol Econ 38(01):91–99. https://doi.org/10.3969/j.issn.1004-910X.2019.01012
32. Steffen B (2018) The importance of project finance for renewable energy projects. Energy Econ 69:280–294. https://doi.org/10.1016/j.eneco.2017.11.006
33. Huang L, Lei Z (2021) How environmental regulation affect corporate green investment: evidence from China. J Clean Prod 279:123560. https://doi.org/10.1016/j.jclepro.2020.123560
34. Septyanto, D., & Nugraha, I. M. (2021). The Influence of Enterprise Risk Management, Leverage, Firm Size and Profitability on Firm Value in Property and Real Estate Companies Listed on the Indonesian Stock Exchange in 2016–2018. KnE Social Sciences,. https://doi.org/10.18502/kss.v5i5.8850
35. Eka, H. (2018). Investment opportunity and industrial growth in Indonesia. International J Busin Soci, 19(2), 295–312. http://repository.undaris.ac.id/id/eprint/113
36. Martínez-Sola C, García-Teruel PJ, Martínez-Solano P (2018) Cash holdings in SMEs: speed of adjustment, growth and financing. Small Business Econ 51(4):823–842. https://doi.org/10.1007/s11187-018-9990-y
37. Xie F, Zhang B (2021) Impact of China's outward foreign direct investment on green total factor productivity in "Belt and Road" participating countries: a perspective of institutional distance. Environ Sci Pollut Res 28(4):4704–4715. https://doi.org/10.1007/s11356-020-10849-2
38. Wang H, Chen Z, Wu X, Nie X (2019) Can a carbon trading system promote the transformation of a low-carbon economy under the framework of the porter hypothesis?—Empirical analysis based on the PSM-DID method. Energy Policy 129:930–938. https://doi.org/10.1016/j.enpol.2019.03.007
39. Wang Y, Shen N (2016) Environmental regulation and environmental productivity: the case of China. Renew Sustain Energy Rev 62:758–766. https://doi.org/10.1016/j.rser.2016.05.048
40. Dong ZQ, Wang H (2019) Local-neighborhood effect of green technology of environmental regulation. China Industr Econ 36:100–118. https://doi.org/10.19581/j.cnki.ciejournal.2019.01.006
41. Falcone PM (2020) Environmental regulation and green investments: The role of green finance. Int J Green Econ 14(2):159–173. https://doi.org/10.1504/IJGE.2020.109735
42. Xu SC, Li YF, Zhang JN, Wang Y, Ma XX, Liu HY et al (2021) Do foreign direct investment and environmental regulation improve green technology innovation? An empirical analysis based on panel data from the Chinese manufacturing industry. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-14648-1
43. Sun Z, Wang X, Liang C, Cao F, Wang L (2021) The impact of heterogeneous environmental regulation on innovation of high-tech enterprises in China: mediating and interaction effect. Environ Sci Pollut Res 28(7):8323–8336. https://doi.org/10.1007/s11356-020-11225-w
44. Wu-gan C, Xiao-liang Z (2017) Dual effect of Chinese environmental regulation on green total factor productivity. Economist. https://doi.org/10.16158/j.cnki.51-1312/f.2017.09.005
45. Zhang, Y., & Sun, C. (2021). Research on the impact of informal environmental regulation on investment of environmental pollution-Based on the perspective of public supervision. In E3S Web of Conferences (Vol. 275, p. 01076). EDP Sciences. https://doi.org/10.1051/e3sconf/202127501076
46. Zhou G, Zhang L, Zhang L (2019) Corporate social responsibility, the atmospheric environment, and technological innovation investment. Sustainability 11(2):481. https://doi.org/10.3390/su11020481

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen journal and benefit from:

- ► Convenient online submission
- ► Rigorous peer review
- ► Open access: articles freely available online
- ► High visibility within the field
- ► Retaining the copyright to your article

Submit your next manuscript at ► springeropen.com