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Environmental Regulation, Technological Progress and Corporate Profit: Empirical Research Based on the Threshold Panel Regression

Andong Liu and Xuesong Gu *

School of Economics and Management, Beijing Forestry University, Beijing 100083, China; lad_1997@163.com
* Correspondence: guxuesong@bjfu.edu.cn; Tel.: +86-01062337379

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Abstract: By assuming a scenario where corporations are facing increasingly stringent environmental regulation, this paper creates a theoretical framework that suggests the mechanism of how environmental regulation impacts corporate profit through the technical level. With a panel data of 900 listed corporations in China's heavily-polluting industries from 2012 to 2016, a dynamic and static panel model and threshold model are built to present the consistency between our theoretical framework and empirical results, which indicate that the influence of environmental regulation has a threshold effect and is dependent on corporate technical level. The robustness tests on the method and variables are conducted to guarantee the robustness of our regressions. The results show that on the one hand, the marginal impacts of environmental regulation and technical level on corporate profit are mutually dependent on each other, and there is a substituting effect of environmental regulation and technical level on stimulating profit growth if the technical level is sufficiently high. On the other hand, when the technical level is lower than a certain value, the interaction effect of environmental regulation and technical level turns into a compounding effect, but corporations are fairly efficient at shifting their technical level to proper ranges where they can increase their profits by taking advantage of environmental regulations.

Keywords: environmental regulation; technological progress; corporate profit

PACS: H23; Q55; Q58

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1. Introduction

Since opening up, China's economy has entered a fast lane and has become the second-largest economy in the world in recent years. However, as the economy develops rapidly, environmental issues are becoming increasingly prominent in this country. A report on pollution in China released by World Bank [1] pointed out that between 2000 and 2005, the total energy consumption in China increased by 70% and the coal consumption increased by 75%, and at the end of the Tenth Five-Year Plan (2001–2005) [2], an assessment of its performance revealed that China's sulfur dioxide and soot emissions were respectively 42% and 11% higher than the targets set at the beginning of the plan. Unfortunately, epidemiological studies have found a consistent connection between air pollution and various consequences, including respiratory symptoms, reduced lung function, chronic bronchitis, and mortality [1]. In China, epidemiological studies have been conducted in Beijing, Shenyang, Shanghai and other cities since the 1980s and 1990s, and the findings suggested that urban air pollution in China can exert serious public health impacts and economic losses on exposed populations. The situation of water pollution is equally severe [1]. For the period 2001–2005, on average, nearly 54% of the seven major rivers of China contained water that was considered unsafe for human consumption, presenting a twelve percent increase since the early 1990s. Moreover, the poor water quality was increasingly owed to non-point sources such as agricultural runoff and urban sewage, impacting greatly and adversely on health outcomes. This bad situation was particularly significant in rural areas, where approximately 300 million people had no access to piped water, as well as among vulnerable groups such as women and children under 5 [1]. The report also attributed excessive cases of diarrhea and excessive deaths resulting from diarrhea in children under 5 in rural areas (only in rural areas) to the shortage of safe water supply. Overall, the deterioration of China's environmental conditions had not been fundamentally curbed. It is thus not surprising that, on December 15, 2011, the State Council of the People's Republic of China promulgated the National Twelfth Five-Year Plan for Environmental Protection, marking the launch of a new round of environmental protection campaigns.

The improvement of environmental quality is what policymakers want to see, but will environmental regulation affect the corporate economic performance? If the answer is yes, then this environmental benefit may be based on the loss of economic development, which raises an important question about whether economic development is incompatible with the improvement of environmental quality. On the issue of how environmental regulation affects corporate profit, technological progress is deemed by most scholars to be a key channel that affects the influence of environmental regulation on corporate profit, yet it has not reached a consensus on a specific mechanism. There are mainly three theories: (1) Based on static standards and fixed technologies, strict environmental regulation restricts firms' competitiveness, leading to rising costs and a decrease in output and efficiency [3–6]; (2) properly-crafted environmental regulation incentivizes technological innovation, improves production efficiency that can be used to compensate environmental costs, and stimulates competitiveness [7–10]; (3) the effect of environmental regulation on corporate economic performance and technological progress is influenced by many factors, and the relationship between them is uncertain [11–14].

The Porter hypothesis [15,16], a representative of the second theory, points out the shortcomings of the first theory and has won the support of most scholars. Many have proved the Porter hypothesis from a theoretical or empirical aspect, but some authors still disagree with this hypothesis. Palmer et al. [17] believe that the conclusion of the Porter hypothesis is not generalizable, and Simpson and Bradford [18] argue that if innovation can make up for environmental costs and even generate excess profits, then corporations have sufficient reasons to innovate even without environmental regulation. More comprehensive reviews of the Porter hypothesis are available in Ambec et al. [19].

The existing or unresolved problems in the current literature are as follows: First, most studies construct their environmental regulation variables by using one specific item, such as sewage charges, greening fees, and pollution control costs, or a combination of several elements, which may be insufficiently representative. Secondly, the existing literature mainly follows the logic that environmental regulation promotes technological progress, which in turn affects corporate profit, ignoring the interaction effect of environmental regulation and technological progress on improving corporate profit. Third, the existing studies often select one or several sub-sectors, such as the chemical industry [20], manufacturing [21] as samples, and use international [22] or provincial [23] macrolevel panel data. The empirical evidence under a huge sample of microlevel data in a large collection of industries is lacking.

In light of the limitations of the current literature, we endeavor to contribute some to this subject matter. First, this paper utilizes a quasi-environmental tax to construct the environmental regulation variable, which is a combination of various environmental-related taxes and administrative fees, comprehensively reflecting corporate expenditures on exploiting, protecting, destructing, and polluting environmental resources. Secondly, we theoretically propose that the impact of environmental regulation and technological progress on the growth of corporate profit has two directions that depend on the technical level. Thirdly, our empirical estimations are based on a large sample that contains all China's heavily-polluting listed corporations for the period 2012–2016, so the conclusions drawn are more representative and convincing.

The remainder of this paper is structured as follows. Section 2 focuses on a theoretical framework. Section 3 presents the variable, data, econometric models and methods. Section 4 exhibits the empirical results and their implications. Ultimately, in Section 5, we draw the conclusions and comment on the study.

2. Theoretical Framework

Environmental regulation is a broad concept. The mainstream environmental regulation tools are divided into four main types: (1) informational (or persuasive), (2) cooperative, (3) regulatory, and (4) economic policy instruments [24]. The fourth is often considered to be the most efficient one because it provides economic incentives that allow recipients to react flexibly. Therefore, in this paper, environmental regulation specifically refers to economic policy instruments. In terms of how environmental regulation affects corporate financial performance, Rassier and Earnhart [25,26] cite a number of studies on this subject matter and write detailed reviews. Hampf and Rødseth [27] argue that a flexible environmental standard leads to more profit for coal-fired power plants in the US than a uniform standard, while Linn and McCormack [28] propose that environmental regulation has little effect on the profits of coal-fired power plants in US. The conclusions of current studies are still mixed, but most are consistent with the Porter hypothesis, which states that "properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them". However, as Rubashkina et al. [29] pointed out, "this proposition was initially formulated in rather general terms". To conduct econometric estimations, we need to construct a more precise framework.

Our theoretical framework is based on the Porter hypothesis and focuses on how corporations react to an increasingly stringent environmental regulation. With other conditions remaining the same, more stringent environmental regulation will inevitably increase the cost of corporations, indicating that their expected profit tends to decline. Before the profit falls, there are two general measures that corporations may take to eliminate this expectation: (1) Cost pass-through; and (2) reducing costs.

Cost pass-through is an act of offsetting increased costs by raising prices. Corporations always have a desire to earn more profits by using cost pass-through, but its prerequisite is fairly strict. On the one hand, the existence of possible price controls legally stifles pass-throughs. On the other hand, even without price controls, pass-throughs will only be seen when corporations have flexibility in setting prices. This flexibility arises from an oligopolistic structure in these large manufacturing sectors with industry (and price) leaders and followers, but this structure can only occur in certain industries. Nevertheless, cost pass-through is still a possible strategy that corporations might adopt to prevent their profits from declining.

Compared to cost pass-through, reducing costs seems to be more feasible. There are several approaches to cut down costs, but what we are interested in are those provoked by environmental regulations. This criterion also applies to the cost pass-through we discussed above. If a measure is taken to decrease the cost or increase the profit by a corporation regardless of the existence of environmental regulations, then it is not the focus of this paper. For example, lowering the wage rate is not what we are concerned about because as long as it is plausible, corporations will do that to lower the cost with or without environmental regulations. Therefore, facing environmental regulations, which is a certain type of cost by nature, corporations have to conceive of approaches to lower this cost. The most effective approach to cope with it is innovation. Before we proceed, it is necessary to justify this proposition. Although innovation happens all the time, even in the absence of environmental regulations, as some might argue, environmental regulation still has its share of incentivizing innovation. Porter and van der Linde [16] enumerated six purposes of a properly-crafted environmental regulation, which comprehensively explained the nexus between environmental regulation and innovation, and they then claimed that as the stringency of regulation increases, the net cost of compliance can decline and may even turn into a net benefit.

We agree that well-designed environmental regulations can act as a spur to technological progress as much empirical evidence shows [30], but we argue that the impact of environmental regulation on corporate profit is contingent on corporate technical level. This argument is based on an assumption that there are diminishing returns to expenditures on raising technical level, so that costs are lower at a low level and higher at a high level.

When the technical level of an environmentally-regulated corporation is low, its cost of innovation is also low. A more stringent environmental regulation then has a stronger effect on improving its technical level, so the benefit arising from the technological progress can offset the environmental burden, leading to an increase in the profit.

However, when the technical level reaches a certain point, it is more difficult for the corporation to continue innovation. What the corporation needs is a lax regulation, instead of a stringent one, which is almost a pure burden and has a slight impact on raising its technical level. Under this circumstance, a more stringent environmental regulation increases the cost and decreases the profit.

In summary, as technical level increases, the role of a gradual environmental regulation in lifting the profit shifts from promoting to stifling.

3. Empirical Design

3.1. Variables and Data

3.1.1. Sample and Data Sources

All corporations in our sample are China's heavily-polluting listed corporations because their environmental information disclosures are more detailed than other types of corporations, which helps to obtain the data. The range of heavily-polluting industries refers to The Guide to Environmental Information Disclosures of Listed Corporations (Draft Version) released by the Ministry of environmental protection of People's Republic of China in 2010, including the industries of thermal power, steel, cement, electrolytic aluminum, coal, metallurgy, chemicals, petrochemicals, building materials, paper, brewing, pharmaceuticals, fermentation, textiles, leather, and mining. According to the classification outcome of the industries of listed corporations in Q2 of 2017 released by the China Securities Regulatory Commission, we select all heavily-polluting listed corporations, 1167 in total. As the research period is 2012–2016, we remove 252 corporations that started to publish their annual reports after 2012, and 15 corporations are also eliminated from our sample due to faults or missing items. Therefore, we obtain a sample of 900 heavily-polluting listed corporations. In addition, our panel data set is balanced.

The data sources of this paper are as follows: (1) Total profits, business incomes, total assets, and total liabilities data are from the Qianzhan database; (2) Producer Price Index (PPI) data originate from the National Bureau of Statistics; (3) the total number of employees and the environmental regulation data are manually extracted from the corporate annual reports.

3.1.2. Main Variables

It follows from the theoretical framework that corporate profit is set as the explained variable, denoted by PRO, and environmental regulation and technical level are main explanatory variables, denoted by ER and TL, respectively. The level of corporate profit is represented by the total profit of each sample corporation. For the setup of the environmental regulation variable, based on the methodology of Bi and Yu [31], we construct a quantitative environmental regulation variable that consists of urban construction maintenance tax, consumption tax, resource tax, cultivated land occupation tax and administrative charges that include: Sewage charges, resource compensation fees, embankment fees, water conservancy construction funds, environmental management funds, environmental protection funds, green fees, land subsidies, fees associated with mining rights, soil and water conservation fees, soil erosion compensation fees, mining drainage water resource fees, mineral resources use fees, paid use of mineral resources, grassland compensation fees, borax reclamation fees, reclamation fees, mineral resources integration fees, vegetation restoration fees, farmland compensation fees, environmental protection fees, sewage treatment fees, forestry fees, environmental sanitation fees, garbage disposal fees, coal management fees, drainage fees.

In the existing literature, technical level is usually estimated using production functions. This paper utilizes a CES production function to estimate technical level. Its general form is as follows:

$$Q = A\left(\delta_1 K^{-\rho} + \delta_2 L^{-\rho}\right)^{-\frac{\mu}{\rho}} \tag{1}$$

In the formula above, A is the technical level coefficient, δ is the distribution coefficient, ρ is the substitution coefficient, and μ is the coefficient of returns to scale. We also assume that the production function exhibits constant returns to scale, i.e., $\delta_1 + \delta_2 = 1$. To estimate the coefficients of the nonlinear CES production function, the second-order Taylor series expansion is performed at $\rho = 0$, and we can take the linear part of ρ that consists of the zero-order, one-order, and two-order terms.

$$\ln Q = \ln A + \mu\delta_1 \ln K + \mu\delta_2 \ln L - \frac{1}{2}\mu\rho\delta_1\delta_2 \ln^2\left(\frac{K}{L}\right) \tag{2}$$

In formula (2), Q denotes the business income, K denotes the total assets, and L denotes the number of employees. After obtaining the values of μ, δ_1, δ_2, and ρ, the values of Q, K, and L of each corporation are substituted into formula (2), so we can calculate A, technical level.

3.1.3. Control Variables

To avoid omitted variables and enhance the accuracy of our estimations, this paper incorporates the following three control variables: (1) Corporate size: Due to the scale effect, a larger scale of a firm is highly associated with higher profitability. It is represented by the natural logarithm of the corporate total assets, denoted by *SIZE*. (2) Financial leverage: A higher financial leverage rate may lead to greater business risk, and firms' profitability can be affected. The ratio of the total debt to the total assets of the corporation is taken as the financial leverage, denoted by *FL*. (3) The Producer Price Index (PPI): This is an index that measures the average change in the ex-factory price of manufacturers. Corporations can earn more profits by selling their products at a higher price captured by the PPI. The index is calculated by taking the average of 12 monthly price indices of the province, in which the corporate address is registered, denoted by *PPI*.

3.2. The Setup of Models and Methods

3.2.1. Classic Models

In this paper, for the sake of applying specific econometric methods, static panel models and dynamic panel models are built. To capture the interaction between environmental regulation and technological progress on corporate profit, we introduce an interaction term of technical level and environmental regulation into the models. Because of the interaction term, we need to strip the partial effects. Therefore, the static panel model is set as follows:

$$\begin{aligned} PRO_{i,t} &= \alpha_0 + \alpha_1 SIZE_{i,t} + \alpha_2 FL_{i,t} + \alpha_3 PPI_{i,t} + \alpha_4\left(ER_{i,t} - \overline{ER_{i,t}}\right) \\ &+ \alpha_5\left(TL_{i,t} - \overline{TL_{i,t}}\right) + \alpha_6\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times \left(TL_{i,t} - \overline{TL_{i,t}}\right) + u_i + \varepsilon_{i,t} \end{aligned} \tag{3}$$

The dynamic panel model is set as follows:

$$\begin{aligned} PRO_{i,t} &= \alpha_0 + \alpha_1 PRO_{i,t-1} + \alpha_2 SIZE_{i,t} + \alpha_3 FL_{i,t} + \alpha_4 PPI_{i,t} + \alpha_5\left(ER_{i,t} - \overline{ER_{i,t}}\right) \\ &+ \alpha_6\left(TL_{i,t} - \overline{TL_{i,t}}\right) + \alpha_7\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times \left(TL_{i,t} - \overline{TL_{i,t}}\right) + u_i + \varepsilon_{i,t} \end{aligned} \tag{4}$$

The α parameters in the two equations are the coefficients to be estimated, α_0 is the constant term, the unobservable random variable u_i is the intercept term representing the individual heterogeneity, $\varepsilon_{i,t}$ is the error term that changes with the individual and time, i represents each corporation in the sample, and t represents the year in the research period.

Additionally, by constructing a new dynamic panel model incorporating an interaction term of environmental regulation and Producer Price Index, we can examine the existence of cost pass-through stimulated by environmental regulation. The model has the following form:

$$\begin{aligned} PRO_{i,t} &= \alpha_0 + \alpha_1 PRO_{i,t-1} + \alpha_2 SIZE_{i,t} + \alpha_3 FL_{i,t} + \alpha_4 TL_{i,t} + \alpha_5\left(ER_{i,t} - \overline{ER_{i,t}}\right) \\ &+ \alpha_6\left(PPI_{i,t} - \overline{PPI_{i,t}}\right) + \alpha_7\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times \left(PPI_{i,t} - \overline{PPI_{i,t}}\right) + u_i + \varepsilon_{i,t} \end{aligned} \tag{5}$$

3.2.2. Threshold Model

The above analysis does not consider the bias in the estimation caused by structural changes. To determine whether the model parameters have undergone structural changes within different technical intervals, the technical level is set as the threshold variable to perform the threshold regression proposed by Hansen [32]. The threshold model with one threshold is shown below:

$$\begin{aligned} PRO_{i,t} &= \alpha_0 + \alpha_1 SIZE_{i,t} + \alpha_2 FL_{i,t} + \alpha_3 PPI_{i,t} + \alpha_4\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) < \gamma\right) \\ &+ \alpha_5\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) > \gamma\right) + \alpha_6\left(TL_{i,t} - \overline{TL_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) < \gamma\right) \\ &+ \alpha_7\left(TL_{i,t} - \overline{TL_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) > \gamma\right) + \alpha_8\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times \left(TL_{i,t} - \overline{TL_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) < \gamma\right) \\ &+ \alpha_9\left(ER_{i,t} - \overline{ER_{i,t}}\right) \times \left(TL_{i,t} - \overline{TL_{i,t}}\right) \times 1\left(\left(TL_{i,t} - \overline{TL_{i,t}}\right) > \gamma\right) + u_i + \varepsilon_{i,t} \end{aligned} \tag{6}$$

In the formula above, 1(*) in equation (6) is an indicator function, which indicates that if the expression in the parentheses is true, it equals 1; otherwise, it equals 0. We only consider how the main explanatory variables are affected by different values of the threshold variable. The control variables are not considered and will not affect the conclusion. Literature often adopts threshold models without incorporating interaction terms, but in this paper, we include it because our interpretations are based on the interaction terms.

3.2.3. Endogeneity and Econometric Methods

Among the variables of the above models, it is unnecessary to consider the endogeneity for financial leverage, Producer Price Index (PPI), and technical level. PPI is an index derived from provincial data, which can be slightly influenced by the profits of individual firms. With regard to financial leverage and technical level, $PRO_{i,t-1}$ has an impact on them, whereas the effect of $PRO_{i,t}$ is negligible. These facts show that there is no two-way causal relationship between these three variables and the explained variable, so there is no obvious endogeneity problem. The endogeneity of these models mainly originates from two factors: First, the environmental tax is involved in the calculation of the corporate profit, indicating that it is easily affected by certain components of the profit; Second, the lag term $PRO_{i,t-1}$, is introduced into the dynamic panel model, which may be highly correlated with the error term.

To overcome the endogeneity, the static panel model is estimated by the instrumental-variables two-stage least-squares (IV-2SLS) method. In this model, the endogenous explanatory variable is environmental regulation, based on the premise of being just identified, the corporate total debt is selected as the instrumental variable. This variable is highly correlated with the endogenous explanatory variable and is an exogenous variable, meeting two features of a good instrumental variable. For the dynamic panel model, the two-step system generalized method of moments (Two-step SYS-GMM) is used to estimate the coefficients. The endogenous variables in the model are $PRO_{i,t-1}$ and $ER_{i,t}$. Additionally, the time dummy variable is controlled in the regressions to enhance the reliability of the results, and the AR (2) value and the Hansen statistic are calculated to test the feasibility of the method and the validity of the instrument variables. Because the sample consists of

900 heavily-polluted listed corporations in different scales and from different industries, there may be heteroscedasticity. Therefore, all the above methods use robust estimations.

4. Empirical Results

4.1. Descriptive Statistics

Table 1 reports the basic statistical features of the variables and lays the groundwork for the empirical analysis below. It can be seen from the table that the correlation coefficients of all variables are below 0.8, which means that there is no obvious correlation in the model. To avoid the spurious regression problem, this paper conducts the unit root tests, and the results indicate each variable is a stationary sequence.

Table 1. Correlated coefficient matrix and statistical features of the variables.

Variables	*PRO*	*SIZE*	*FL*	*PPI*	*ER*	*TL*
PRO	1					
SIZE	0.3603	1				
FL	−0.0580	0.2062	1			
PPI	0.0470	−0.0638	−0.0447	1		
ER	0.2848	0.2104	0.0135	−0.0050	1	
TL	0.1545	0.3738	0.1321	0.0477	0.1495	1
Obs	4500	4500	4500	4500	4500	4500
Unit	10,000 RMB		%		10,000 RMB	
Mean	39,083.77	12.91447	0.44293	97.50708	5160.687	1.19091074
SD	159,343.5	1.23639	0.296336	2.336314	37,347.01	0.04991093
Min	−1,597,452	6.906364	0.01397	82.4	0	0.882530115
Max	2,515,394	17.24762	10.08224	102.9833	1,292,375	1.633192319
Fisher-ADF	50.3676 ***	58.5058 ***	53.2438 ***	41.1643 ***	29.5559 ***	34.9336 ***
LLC	−39.4344 ***	−1.2e + 02 ***	−5.2e + 02 ***	−86.0141 ***	−29.5002 ***	−86.2265 ***

Note: *** indicates significance at the 1%level.

4.2. Empirical Analysis

4.2.1. Classic Models

For the dynamic panel models, the SYS-GMM method is used for the regression analysis. To enhance the reliability of the conclusions, three models are set for comparison. The results are shown in Table 2.

According to the results of Table 2, the Wald test strongly rejects its null hypothesis, indicating that the overall significance level of the models is high; For column (1), (2) and (3), the p-values of Hansen statistics are greater than 0.05. Therefore, the hypothesis that the instrumental variables are over-identified cannot be rejected, demonstrating that the instrumental variables are valid; the AR (2) values are around 0.2, which means that the residual terms of the models do not have sequence correlation, which is consistent with the prerequisite of using SYS-GMM. All coefficients are significant except the coefficient of $TL_{i,t}$ in column (3), but this issue will not affect the empirical results [33].

Due to the interaction terms in these models, our interpretations are based on the coefficients of environmental regulation and technical level and their interaction term.

The marginal impact of environmental regulation on the profit of a certain corporation is dependent on its technical level. When technical level is low, environmental regulation promotes its profit, but this effect diminishes as technical level increases. When the corporation reaches a certain technical level, the effect of environmental regulation begins reducing its profit and intensifies as technical level rises. These results are in line with our theoretical framework. Environmental regulation acts as a spur to the growth of corporate profit via incentivizing the technological progress of corporations with a low technical level. Once technical level is sufficiently high, a more stringent environmental regulation has a negligible effect on innovation and becomes a heavier burden for corporations, leading to the fall of corporate profit.

Table 2. The results of the dynamic panel model.

Variables	(1)	(2)	(3)
$PRO_{i,t-1}$	0.4217148 ** [0.026]	0.3287825 * [0.057]	0.3349011 * [0.053]
$SIZE_{i,t}$	0.1439889 *** [0.000]	0.1179818 *** [0.000]	0.1104433 *** [0.000]
$FL_{i,t}$	−0.2408839 *** [0.000]	−0.3132601 *** [0.000]	−0.304236 *** [0.000]
$PPI_{i,t}$	0.1116784 *** [0.000]	0.1297603 *** [0.000]	0.1318829 *** [0.000]
$ER_{i,t}$	0.1424759 ** [0.026]	12.59488 *** [0.000]	1.704724 *** [0.001]
$TL_{i,t}$	0.0637427 ** [0.021]	0.0804511 *** [0.002]	0.0236171 [0.357]
$ER_{i,t} \times TL_{i,t}$		−15.09975 *** [0.000]	−15.95672 *** [0.002]
Constant Term	−0.2420425 *** [0.000]	−0.2504791 *** [0.000]	−0.1822678 *** [0.000]
Time Dummy Variable	Controlled	Controlled	Controlled
Wald	173.93 [0.000]	305.59 [0.000]	319.24 [0.000]
Hansen	34.59 [0.057]	28.72 [0.190]	26.32 [0.286]
Arellano-Bond AR (1)	−1.98 [0.047]	−2.00 [0.046]	−1.98 [0.047]
Arellano-Bond AR (2)	1.24 [0.215]	1.28 [0.201]	1.31 [0.189]

Note: ***, ** or * denote significance at the level 1%, 5%, or 10%, respectively. Figures in square brackets are *p*-values, similarly hereinafter. Column (1) is the model without the interaction term, column (2) is the model with the interaction term but fails to strip the partial effects, and column (3) strips the partial effects on the basis of column (2), similarly hereinafter.

Based on how we construct the interaction term and the results we obtain, technical level is symmetrical with environmental regulation in the sense that the marginal impact of technical level depends on the stringency of the environmental regulation, and they exhibit the same trend. This shows a substituting effect of environmental regulation and technical level on stimulating profit growth. The implication is that, from the perspective of promoting corporate profit, for corporations with a low technical level a stringent environmental regulation is preferable, or equivalently, corporations with a high technical level operate better with lax environmental regulations.

With respect to other variables, the lag terms are significantly positive in all three models, demonstrating that corporate profit has strong inertia. For the coefficients in columns (1), (2) and (3), control variables are consistent and highly significant, indicating that the selection of control variables is reasonable. A larger corporate size can contribute to greater profitability due to economies of scale. Corporations with a higher financial leverage rate may incur a higher business risk, and their profitability might be also adversely affected. A higher Producer Price Index is associated with higher ex-factory prices, which tend to bring more profits for corporations.

In regard to the existence of cost pass-through, we expect that it is less likely to see pass-through because most of the corporations in our sample are in nearly perfectly competitive markets. The regression results are shown in Table 3, and the interaction term is highly insignificant, which is consistent with our expectations.

Table 3. The results of the test on the existence of cost pass-through.

Variables	(1)	(2)
$PRO_{i,t-1}$	0.4752714 *** [0.006]	0.4415068 ** [0.034]
$SIZE_{i,t}$	0.125101 *** [0.000]	0.1203363 *** [0.002]
$FL_{i,t}$	−0.2247939 *** [0.001]	−0.2297733 *** [0.005]
$TL_{i,t}$	0.0638242 *** [0.007]	0.064476 ** [0.012]
$ER_{i,t}$	0.157292 [0.929]	0.2308772 ** [0.024]
$PPI_{i,t}$	0.1033135 *** [0.000]	0.0913139 *** [0.008]
$ER_{i,t} \times PPI_{i,t}$	0.1263593 [0.949]	1.560135 [0.620]
Constant Term	−0.2216543 *** [0.000]	−0.1194233 *** [0.001]
Time Dummy Variable	Controlled	Controlled
Wald	204.03 [0.000]	178.56 [0.000]
Hansen	33.04 [0.080]	39.05 [0.020]
Arellano-Bond AR (1)	−2.01 [0.045]	−1.97 [0.049]
Arellano-Bond AR (2)	1.37 [0.169]	1.29 [0.198]

Note: *** or ** denote significance at the level 1% or 5%, respectively. Column (1) is the model with the interaction term but fails to strip the partial effects, and column (2) strips the partial effects on the basis of column (1).

4.2.2. Threshold Model

To determine the existence of the threshold effect and the number of thresholds, relative tests are conducted in this article. It follows from the theoretical framework that the technical level is set as the threshold variable, which has a threshold effect as the results in Table 4 suggest.

Table 4. Threshold effect test and the estimation of the threshold value.

	Estimated Values			*p*-Values
Single Threshold	0.0426			0.0000
Double threshold	0.0426	0.0399		0.0200
Triple Threshold	0.0426	0.0399	0.0169	0.5467

Note: Due to the interaction term and the need for removing its partial effect, the actual threshold variable is $TL'_{i,t} = TL_{i,t} - \overline{TL_{i,t}}$

Table 4 also rejects the existence of a triple threshold. Table 5 below shows the results of the threshold regressions based on a single threshold and double threshold. With respect to the control variables, they are highly significant, and their signs are consistent with the previous regressions, so we only focus on the main variables.

Table 5. The results of threshold regression.

	Single Threshold		Double Threshold		
Interval	$TL'_{i,t} < 0.0426$	$TL'_{i,t} \geq 0.0426$	$TL'_{i,t} < 0.0399$	$0.0399 \leq TL'_{i,t} \leq 0.0426$	$TL'_{i,t} > 0.0426$
$ER_{i,t}$	−0.3096498 *** [0.010]	2.347842 *** [0.000]	−0.2825093 ** [0.016]	205.4091 *** [0.000]	2.879538 *** [0.000]
$TL_{i,t}$	0.4880592 *** [0.000]	0.1353165 *** [0.001]	0.4310415 *** [0.000]	0.5659494 *** [0.000]	0.1670793 *** [0.000]
$ER_{i,t} \times TL_{i,t}$	66.34463 *** [0.000]	−18.26272 *** [0.000]	57.16775 *** [0.000]	−4860.675 *** [0.000]	−23.28773 *** [0.000]
$SIZE_{i,t}$	0.1381697 *** [0.000]			0.1408062 *** [0.000]	
$FL_{i,t}$	−0.0984097 *** [0.000]			−0.0987927 *** [0.000]	
$PPI_{i,t}$	0.0844517 *** [0.001]			0.0893627 *** [0.000]	
Constant Term	−0.1659292 *** [0.000]			−0.1728245 *** [0.000]	

Note: *** or ** denote significance at the level 1% or 5%, respectively.

Both regressions suggest that the effect of environmental regulation and technical level on the corporate profit has the same trend as the results of the classic models when technical level exceeds a certain level, which is a supplement to our theoretical framework where we fail to specify whether there is a threshold to cross to enable our theory to work. It is reasonable to assume that corporations with a very low technical level are either insensitive to technological progress or relatively small entities that are busy with handling other issues instead of paying their attention to long-term strategies, such as innovation. Environmental regulation is thus a nearly pure burden for corporations with a very low technical level, which is also the case for corporations with a very high technical level, as our classic models imply. An apparent difference between the results of the two regressions is that compared to the single-threshold regression, the double-threshold regression contains a new interval in the middle that exhibits a strong substituting effect of environmental regulation and technical level, indicating that corporations in this interval either suffer from or benefit from environmental regulation greatly. The interaction terms implicitly include turning points that act as thresholds, so we can visualize how environmental regulation interacts with technical level to affect corporate profit. Formula (7) shows the method we use to calculate the average marginal impact (AMI) of environmental regulation on the profits of our sample corporations:

$$AMI = \frac{\int_a^b \left(\alpha + \beta \cdot TL'_{i,t}\right) dTL'_{i,t}}{b - a} \quad (7)$$

where a and b are the lower and upper bound of the technical interval, α is the coefficient of environmental regulation and β is the coefficient of the interaction term.

Based on the double-threshold model, Table 6 shows the results of the AMIs in different technical intervals and also reports the distribution of the 4500 observations in these intervals.

Table 6. The results of AMIs and the distribution of observations.

	Interval (1) [−0.1888,0.0049]	**Interval (2) [0.0049,0.0399]**	**Interval (3) [0.0399,0.0423]**	**Interval (4) [0.0423,0.0426]**	**Interval (5) [0.0426,0.1237]**	**Interval (6) [0.1237,0.2708]**
AMI	−5.5391	0.9980	5.6354	−0.9266	0.9432	−1.7140
Observations	2712	1412	49	8	310	9

According to Table 6, more than 60% of the observations in our sample are affected adversely by environmental regulation, and the effect is relatively strong. When the technical level of corporations falls into the interval (3), the impact reaches its maximum. Another finding is that comparatively fewer corporations are in the interval (4) and (6) where environmental regulation stifles the growth of their profits. This implies that corporations might have a certain degree of flexibility in adjusting their technical level to enable them to benefit from environmental regulation rather than suffering from it.

4.3. Robustness Test

4.3.1. Robustness Test on Method

In the above, the dynamic panel model is estimated by SYS-GMM, and we draw the corresponding conclusions. If another method is used and a similar conclusion can be drawn, then the method of estimating the model is robust and the credibility of the conclusions will be greatly improved. In this part, initially, we apply the first difference to the fixed-effect model, then utilize the instrumental-variables two-stage least-squares (IV-2SLS) method to estimate the static panel model and use the Limited Information Maximum Likelihood (LIML) method to test the validity of the instrumental variables. The regression results are shown in Table 7. The signs of the variables are consistent with the previous regressions, but variable $TL_{i,t}$ is insignificant, which will not affect the conclusions (the reasons are stated before). Therefore, the method is robust, and the conclusions are highly reliable. In addition, the results of LIML show that there is no weak instrument problem in the models.

Table 7. The results of the robustness test on the method.

Variables	(1)	(2)	(3)
$SIZE_{i,t}$	0.1108783 * [0.096]	0.1030831 ** [0.021]	0.1045855 ** [0.017]
$FL_{i,t}$	−0.1111877 ** [0.028]	−0.1258773 *** [0.000]	−0.123046 *** [0.000]
$PPI_{i,t}$	0.1053747 *** [0.006]	0.1046677 *** [0.000]	0.1048039 *** [0.000]
$ER_{i,t}$	7.010789 *** [0.007]	52.1362 *** [0.000]	5.916654 *** [0.000]
$TL_{i,t}$	0.1382362 ** [0.034]	0.2402071 *** [0.000]	0.0150746 [0.800]
$ER_{i,t} \times TL_{i,t}$		−63.74286 *** [0.000]	−51.45717 *** [0.000]
Constant Term	−0.0021075 [0.132]	−0.0009698 [0.247]	−0.0011891 [0.151]
Anderson canon. corr. LM statistic	8.585 [0.0034]	42.592 [0.0000]	48.634 [0.0000]
Cragg-Donald Wald F statistic	8.591	43.018	49.204

Note: ***, ** or * denote significance at the level 1%, 5%, or 10%, respectively.

4.3.2. Robustness Test on Variable

The environmental regulation variable in this paper consists of four types of taxes and many types of administrative charges. A large part of administrative fees are fees charged by local governments, which implies that geographical features may affect the stringency of environmental regulation on corporations in the sample, indicating that the stability of variables can be to some extent affected. Consequently, we eliminate all the administrative charges and only use the four taxes to reconstruct the environmental regulation variable, and SYS-GMM is carried out to re-estimate the models after divesting the partial effects. The regression results are shown in Table 8. All signs are in line with the results of the previous estimations, and various test statistics satisfy the requirements. Therefore, the selection of the variable is robust.

Table 8. The results of the robustness test on variables.

Variables	(1)	(2)	(3)
$PRO_{i,t-1}$	0.4375242 ** [0.013]	0.3579402 ** [0.033]	0.3861617 ** [0.023]
$SIZE_{i,t}$	0.1244942 *** [0.000]	0.117298 *** [0.000]	0.1177454 *** [0.000]
$FL_{i,t}$	−0.2416338 *** [0.000]	−0.279773 *** [0.000]	−0.2651277 *** [0.000]
$PPI_{i,t}$	0.1133783 *** [0.000]	0.1248609 *** [0.000]	0.114665 *** [0.000]
$ER_{i,t}$	0.3179719 ** [0.023]	5.406993 *** [0.008]	0.7024571 *** [0.000]
$TL_{i,t}$	0.0707413 ** [0.002]	0.084866 *** [0.001]	0.0443369 * [0.070]
$ER_{i,t} \times TL_{i,t}$		−6.459247 ** [0.011]	−5.560608 *** [0.007]
Constant Term	−0.2350895 *** [0.000]	−0.24944 *** [0.000]	−0.1750279 *** [0.000]
Time Dummy Variable	Controlled	Controlled	Controlled
Wald	217.96 [0.000]	527.54 [0.000]	726.36 [0.000]
Hansen	31.39 [0.114]	27.81 [0.223]	29.57 [0.162]
Arellano-Bond AR (1)	−2.01 [0.044]	−2.03 [0.042]	−2.02 [0.043]
Arellano-Bond AR (2)	1.34 [0.181]	1.28 [0.200]	1.34 [0.180]

Note: ***, ** or * denote significance at the level 1%, 5%, or 10%, respectively.

5. Discussion

The nature of the nexus between environmental regulation and corporate financial performance is still in dispute, as our introduction section shows. Some scholars hold the traditional view that environmental regulation exerts detrimental impacts on corporations financially, while most agree with the Porter hypothesis. We argue that the reason why researchers in this field end up with contrasting results is that they often use corporations in one industry as their samples, leading to divergent conclusions due to different natures of corporations from different industries. It might be reasonable to argue that there are certain types of corporations that are very sensitive to technology, while others may not regard technology as a crucial part of their production. By nature, corporations are thus distributed at different technical intervals. Based on the sample containing 16 industries, our results precisely suggest a mechanism according to which under different technical levels, corporate profitability can benefit or suffer from environmental regulation, which can be considered consistent with both views mentioned above. We are not attempting to resolve the dispute in this subject matter, but the mechanism we suggest might to some extent contribute to the understanding of how environmental regulation impacts corporate profit and why previous studies fail to reach a consensus.

We should also point out the limitations of this paper. Due to the difficulty of manually collecting data, our sample only contains five-year data. Extending the period of our sample data can help us confirm if the results remain the same in the long run. Moreover, when facing environmental regulations, corporations can choose to move to places with lax regulations, or they are forced to withdraw from the market. Although very few corporations end up moving or withdrawing, it is worth considering these factors.

6. Conclusions

Based on how corporations react to more stringent environmental regulations to control their costs, this paper constructs a theoretical framework suggesting that the impact of an environmental regulation on corporate profit has a threshold effect and is contingent on the corporate technical level. Through employing a panel data of 900 listed corporations in China's heavily-polluting industries from 2012 to 2016, dynamic and static panel models and threshold models are used to reveal that the empirical results are in line with the mechanism proposed in the theoretical framework. In addition, the robustness tests on the method and variables are carried out to ensure the robustness of our regressions.

The results show that: (1) The marginal impact of environmental regulation on corporate profit is dependent on the technical level. The effect changes from positive to negative as technology advances. Technical level is symmetrical to environmental regulation, in the sense that the marginal impact of the technical level relies on the stringency of the environmental regulation and exhibits an identical trend. There is a substituting effect of environmental regulation and technical level on stimulating profit growth. (2) When technical level is sufficiently low, the effect of environmental regulation and technical level is not substituting, but compounding, which is what the majority of corporations in our sample are undergoing. Most of them are in fact suffering from the adverse effect of environmental regulation on their profits. (3) Corporations, to some extent, are efficient at adjusting their technical level to match the right level at which they can take advantage of the environmental regulation and increase their profits.

Our findings suggest some policy implications. First, an environmental regulation can bring economic benefits to the economy of China as long as it is well-designed. Second, governments should pay more attention to corporations with a very low technical level because environmental regulation has a limited effect on stimulating their innovations and exerts an adverse impact on profit. Other incentives should thus be considered to improve their technology to a certain level, such as subsidies, so that when the technical level of corporations reaches a proper position, environmental regulation can start to positively influence their profits. Third, governments need carefully devise their environmental regulation policies to guarantee that the profits of corporations with a fairly high technical level will not be adversely influenced by environmental regulations. In short, environmental regulation policymakers should endeavor to craft policy properly to bring players who are at the bottom or on the top in the sense of their technical levels back to the game in the middle, where they can take full advantage of the environmental regulations and win the rewards.

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References

1. Cost of Pollution in China: Economic Estimates of Physical Damages. 2007. World Bank Website. Available online: http://documents.worldbank.org/curated/en/782171468027560055/Cost-of-pollution-in-China-economic-estimates-of-physical-damages (accessed on 1 January 2020).
2. The National People's Congress of the People's Republic of China. *Report on the Outline of the Tenth Five-Year Plan for National Economic and Social Development*; The People's Republic of China: Beijing, China, 2001. Available online: http://www.npc.gov.cn/zgrdw/englishnpc/Special_11_5/2010-03/03/content_1690620.htm (accessed on 1 January 2020).
3. Wagner, M. On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms. *Res. Policy* **2007**, *36*, 1587–1602. [CrossRef]

4. Chintrakarn, P. Environmental regulation and U.S. states' technical inefficiency. *Econ. Lett.* **2008**, *100*, 363–365. [CrossRef]
5. Sueyoshi, T.; Goto, M.; Shang, J. Core business concentration vs. corporate diversification in the US electric utility industry: Synergy and deregulation effects. *Energy Policy* **2009**, *39*, 4583–4594. [CrossRef]
6. Ramanathan, R.; Black, A.; Nath, P.; Muyldermans, L. Impact of environmental regulations on innovation and performance in the UK industrial sector. *Manag. Decis.* **2010**, *48*, 1493–1513. [CrossRef]
7. Hamamoto, M. Environmental regulation and the productivity of Japanese industries. *Resour. Energy Econ.* **2006**, *28*, 299–312. [CrossRef]
8. Cole, M.; Elliott, R.; Okubo, T. Trade, environmental regulations and industrial mobility: An industry-level study of Japan. *Ecol. Econ.* **2010**, *69*, 1995–2002. [CrossRef]
9. Zhang, C.; Lu, Y.; Guo, L.; Yu, T. The intensity of environmental regulation and technological progress of production. *Econ. Res. J.* **2011**, *2*, 113–124.
10. Costantini, V.; Mazzanti, M. On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. *Res. Policy* **2012**, *41*, 132–153. [CrossRef]
11. Ambec, S.; Barla, P. Can environmental regulations be good for business? *An assessment of the Porter hypothesis. Energy Stud. Rev.* **2006**, *14*, 601–610. [CrossRef]
12. Lanoie, P.; Laurent-Lucchetti, J.; Johnstone, N.; Ambec, S. Environmental policy, innovation and performance: New insights on the Porter hypothesis. *J. Econ. Manag. Strategy* **2011**, *20*, 803–842. [CrossRef]
13. Rexhäuser, S.; Rammer, C. Environmental innovations and firm profitability: Unmasking the Porter hypothesis. *Environ. Resour. Econ.* **2014**, *57*, 145–167. [CrossRef]
14. Sen, S. Corporate Governance, environmental regulations and technological change. *Eur. Econ. Rev.* **2015**, *80*, 36–61. [CrossRef]
15. Porter, M.E. America's green strategy. *Sci. Am.* **1991**, *264*, 168. [CrossRef]
16. Porter, M.E.; van der Linde, C. Toward a new conception of the environment-competitiveness relationship. *J. Econ. Perspect.* **1995**, *9*, 97–118. [CrossRef]
17. Palmer, K.; Oates, W.E.; Portney, P.R. Tightening environmental standards: The benefit-cost or the no-cost paradigm? *J. Econ. Perspect.* **1995**, *9*, 119–132. [CrossRef]
18. Simpson, R.D.; Bradford, R.L., III. Taxing variable cost: Environmental regulation as industrial policy. *J. Environ. Econ. Manag.* **1996**, *30*, 282–300. [CrossRef]
19. Ambec, S.; Cohen, M.A.; Elgie, S.; Lanoie, P. The Porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? *Rev. Environ. Econ. Policy* **2013**, *7*, 2–22. [CrossRef]
20. Rassier, D.G.; Earnhart, D. The effect of clean water regulation on profitability: Testing the Porter hypothesis. *Land Econ.* **2010**, *86*, 329–344. [CrossRef]
21. Kneller, R.; Manderson, E. Environmental Regulations and Innovation activity in UK Manufacturing Industries. *Resour. Energy Econ.* **2012**, *34*, 211–235. [CrossRef]
22. Wang, B.; Wu, Y.; Yan, P. Environmental regulation and total factor productivity growth: An empirical study of the APEC economies. *Econ. Res. J.* **2008**, *5*, 19–32.
23. Zhang, C.; Liu, H.; Bressers, H.T.A.; Buchanan, K.S. Productivity growth and environmental regulations—Accounting for undesirable outputs: Analysis of China's thirty provincial regions using the Malmquist-Luenberger index. *Ecol. Econ.* **2011**, *70*, 2369–2379. [CrossRef]
24. Böcher, M. A theoretical framework for explaining the choice of instruments in environmental policy. *Forest Policy Econ.* **2012**, *16*, 14–22. [CrossRef]
25. Rassier, D.G.; Earnhart, D. Short-run and long-run implications of environmental regulation on financial performance. *Contemp. Econ. Policy* **2011**, *29*, 357–373. [CrossRef]
26. Rassier, D.G.; Earnhart, D. Effects of environmental regulation on actual and expected profitability. *Ecol. Econ.* **2015**, *112*, 129–140. [CrossRef]
27. Hampf, B.; Rødseth, K.L. Optimal profits under environmental regulation: The benefits from emission intensity averaging. *Ann. Oper. Res.* **2017**, *255*, 367–390. [CrossRef]
28. Linn, J.; McCormack, K. The roles of energy markets and environmental regulation in reducing coal-fired plant profits and electricity sector emissions. *Rand J. Econ.* **2019**, *50*, 733–767. [CrossRef]
29. Rubashkina, Y.; Galeotti, M.; Verdolini, E. Environmental regulation and competitiveness: Empirical evidence on the Porter hypothesis from European manufacturing sectors. *Energy Policy* **2015**, *83*, 288–300. [CrossRef]

30. Jiang, F.X.; Wang, Z.J.; Bai, J.H. The Dual Effect of Environmental Regulations' Impact on Innovation—An Empirical Study Based on Dynamic Panel Data of Jiangsu Manufacturing. *China Ind. Econ.* **2013**, *7*, 44–55. (In Chinese)
31. Bi, Q.; Yu, L. Relationship between environmental taxes and enterprise green investment behavior: A panel quantile regression approach (In Chinese). *China Popul. Resour. Environ.* **2016**, *26*, 76–82.
32. Hansen, B.E. Threshold effects in non-dynamic panels: Estimation, testing, and inference. *J. Econom.* **1999**, *93*, 345–368. [CrossRef]
33. Cohen, J. Partialed products are interactions; partialed powers are curve components. *Psychol. Bull.* **1978**, *85*, 858–866. [CrossRef]