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Research Article

Improvement of Different Types of Environmental Regulations on Total Factor Productivity: A Threshold Effect Analysis

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Based on the distinction of different types of environmental regulations, this paper attempts to test the threshold effect of environmental regulation on the total factor productivity (TFP) by employing a panel threshold model and a province-level panel data set during 2006–2016. Research results show that the influence of command-and-control and market incentive environmental regulation on the total factor productivity has a single threshold conversion characteristic of foreign direct investment (FDI) and financial scale, but the impact behavior and influence degree around the threshold are inconsistent. The effect of voluntary conscious environmental regulation on the total factor productivity has a single threshold conversion feature of human capital, and moderately enhanced intensity of environmental regulation is conducive to promoting the total factor productivity after crossing the threshold. Finally, in order to enhance the regional total factor productivity, relevant policy recommendations are proposed.

1. Introduction

Since the four decades of reform and opening, industrialization and urbanization in China have improved rapidly, which has made great contribution to the steady increase of state revenue and residents' disposable income. However, this development mode driven by the production resource is unsustainable, which produced a large number of environmental pollutants. National Bureau of Statistics data show that the one-time energy consumption in the whole country amounted to 4.3 billion yuan of standard coal in 2015, and the energy consumption of fossil fuels reached 88% of the total. At the same time, many environmental pollutants were produced. Industrial waste water reached 19.55 billion tons, industrial SO_2 was 15.57 million tons, and industrial solid waste was 3.27 billion tons. On the urban ambient air quality, for example, there are 338 cities at the prefecture level, and only 73 cities reached the ambient air quality standard, accounting for only 21.6%. The average proportion of days which reach the standard for all prefecture-level cities is 76.7%, and the average exceeding proportion is 23.3%. How to achieve the win-win development model of economic growth and environmental governance is particularly important. It is the common aspiration of the government, enterprises, and residents.

As the competent department of environmental management, government formulates strict emission standards on enterprise sewage and living sewage through the legal tools to reduce environmental pollutant emissions and provide an excellent environment for residents. But it is bound to increase the expenditure of emission unqualified corporate, such as purchasing equipment and hiring maintenance personnel, which will lead to the increase of short-term business spending significantly. From the dynamic view, some scholars believe that purchase of advanced equipment and training of qualified personnel can compensate for additional costs. The mechanism of compensate is improving enterprise market competitiveness and high-quality differentiated products in a long term [1–4]. The theory is called the strong Porter hypothesis. From the

dynamic perspective, the technological progress will induce the scale effect, technological effect, and structural effect, which may increase the total amount of pollutant emissions to some extent. With the improvement of the residents' income level, the demand for higher quality environmental public resources is more intense. Regulators will further enhance environmental regulation standards under pressure and further increase the difficulty of environmental protection. In this way, the core of solving the above paradox through environmental regulation is whether reasonable environmental regulation can improve the total factor productivity.

In view of the above-mentioned problems, this paper constructs the panel threshold model based on the analysis of existing research from the perspective of environmental regulation classification and analyzes the threshold conversion characteristics of environmental regulation on the total factor productivity. The main target is to offer advice for promoting the coordinated development of environmental protection and economic growth. This paper is structured as follows: Section 2 reviews the related literature. Section 3 briefly describes the existing measure state of the total factor productivity and environmental regulation. In Section 4, the influence mechanism of the TFP threshold effect on environmental regulation is analyzed. The research design and empirical analysis are presented in Section 5. Section 6 summarizes this paper and provides its policy suggestion.

2. Literature Review

With the development of the Porter hypothesis, a large number of scholars have explored the relationship between environmental regulation and the TFP from two aspects of theory and demonstration to provide the scientific policy for the region's economic development [5–12]. However, there are differences between scholars' conclusions, such as the time dimension, regional heterogeneity, the adjustment of environmental regulation intensity, and the relevance of regional competition. From the perspective of relevance, there are three main viewpoints: not supporting the strong Porter hypothesis, supporting the Porter hypothesis, and supporting the conditional strong Porter hypothesis.

Some scholars believe that environmental regulation will lead to the decline of the TFP, and most of these studies are concentrated in the early stage. Barbera and McConnell [13] took 5 heavy-polluting industries in the United States as an example to explore the correlation between the cutting of production cost and the productivity. It is found that the correlation is negative, and the increase in production costs by 1% resulted in a decline in the TFP by 10%–30%. Body and McClelland [14] took the US paper industry as an example to study the relationship between the environmental governance and the total factor productivity. It is found that environmental management expenditure has a significant crowding-out effect on the investment in other aspects, and environmental governance spending for every increase of 1% will result in a paper industry productivity decline of 9.4%. Gray and Shadbegian [15] took the milk industry as an example for further analysis and found that environmental regulation expenditure for each 1% increase will result in the industry productivity decrease by 9.3%. Becker [16] and Lanoie et al. [17] found that the strong Porter hypothesis does not hold from the perspective of manufacturing and enterprise innovation.

Some scholars believe that appropriate environmental regulation is conducive to the promotion of the TFP, and most of them are based on perspective of dynamic research, and methods of measuring the TFP. Peuckert [18] considered dynamic characteristics of the effect of environmental regulation and constructed a dynamic measurement model. It is found that environmental regulation is conducive to improving the total factor productivity in the long term, which means that the innovation compensation effect is significant. Guo and Zhang [19] considered the direct and indirect effects of environmental regulation on the total factor productivity by using provincial panel data of China's industrial enterprises in 1998–2012. The research showed that the impact of environmental regulation on R&D investment is obvious, and the direct effect and indirect effect of productivity caused by R&D investment are significant, which indicates that environmental regulation has a significant innovation compensation effect. Some scholars also analyzed the change of environmental regulation measures and total factor productivity measures and further supported the strong Porter hypothesis [20–22].

The main reason for the above two opposite research conclusions is the difference of environmental regulation intensity and the derivation of environmental regulation tools, which indicates the existence of the conditional strong Porter hypothesis. Li et al. [23] constructed a panel threshold model to explore the impact of environmental regulation and the TFP and found that there is a significant threshold effect between the two; however, the research lacks the classification of environmental regulation. In addition, some scholars divide environmental regulation into government environmental regulation and individual environmental regulation on the basis of its subject, or divide it into the command-and-control type, market incentive type, and resource conscious type based on the angle of environmental regulation tools [24–26]. But the threshold setting is still the strength of environmental regulation itself. Based on this point of view, this paper constructs a panel threshold measurement model to validate the strong Porter hypothesis.

3. Measurement of Total Factor Productivity and Environmental Regulation

3.1. Total Factor Productivity. The main methods of measuring the total factor productivity are stochastic frontier analysis (SFA) and nonparametric data envelopment analysis (DEA) methods. The SFA method relies on the parameter setting, and the DEA method is independent of parameters, which avoids the deviations caused by the parameters. The early total factor productivity measurement did not consider undesirable outputs (mainly

industrial pollutants), and all types of outputs were set as desirable outputs. The DEA method is divided into radial and nonradial types; the former assumes that the input variables or output variables are expanded in the same proportion, and the assumption of the latter is that the input variables or output variables are effectively adjusted based on the amount of slack to improve the validity of the measure. Referring to the approach of Li and Wu [4], this paper uses the EBM-DEA model proposed by Tone and Tsutsui [27], and the model has both radial and nonradial features. Considering the energy inputs and undesirable outputs, the calculation in this paper is done by referring to the Malmquist–Luenberger (ML) productivity index proposed by Chung et al. [28]. However, the above model may have infeasible solutions in the process of calculation. Oh [29] proposed the global Malmquist–Luenberger productivity index under the global technical conditions, which can overcome the problem of no feasible solution. Then, the EBM-ML DEA model will be used to calculate the total factor productivity, and the corresponding definition is as follows.

In line with the research of Chung et al. [28] and Simar and Wilson [30, 31], we can get

$$\begin{aligned} D_0(x, y, b; g) &= \sup\{\theta:\ (y, b) \in P(x)\}, \\ g &= (y, -b), \\ P(x) &= \{(y, b)\}, \end{aligned} \tag{1}$$

where x is inputs of decision-making units (DMU_S), y is good outputs, b is bad outputs, D_0 denotes the directional distance function for DMU_0, $P(x)$ represents the production possibility set (PPS), g indicates the directional vector, sup stands for the upper limit function, and θ is the efficiency parameter. Furthermore, Färe et al. [32] developed the directional distance function, which can help decrease bad outputs and increase good outputs. And the corresponding directional distance function is rewritten as follows:

$$\begin{aligned} & D_0(x, y, b; g) = Max\theta, \\ \text{s.t.}\quad & \sum_{n=1}^{N} z_n x_{in} \le x_{i0}, \quad i = 1, 2, \ldots, I, \\ & \sum_{n=1}^{N} z_n y_{jn} \ge y_{j0} + \theta y_{j0}, \quad j = 1, 2, \ldots, J, \\ & \sum_{n=1}^{N} z_n b_{kn} \ge b_{k0} - \theta b_{k0}, \quad k = 1, 2, \ldots, K, \\ & z_n \ge 0, \quad n = 1, 2, \ldots, N, \end{aligned} \tag{2}$$

where D_0 represents the distance of DMU_0 from the efficiency frontier and z_n denotes the multiplier variable. What needs to be emphasized is that the model (2) is assumption that good outputs and bad outputs take the same radial change rather than the direction, which cannot represent the technological progress. In order to solve the above problem, Färe and Grosskopf [33] formulated a new method that assumed different slack quantities between good outputs and bad outputs. The corresponding nonradial ameliorated model is written as follows:

$$\begin{aligned} & D_0(x, y, b; g) = \sup\left\{\left(\sum_j \beta_j + \sum_k \tau_k\right):\ (y, b) + \left(\beta_j - \tau_k\right)\right\} \\ \text{s.t.}\quad & \sum_{n=1}^{N} z_n x_{in} \le x_{i0}, \quad i = 1, 2, \ldots, I, \\ & \sum_{n=1}^{N} z_n y_{jn} \ge y_{j0} + \beta_j, \quad j = 1, 2, \ldots, J, \\ & \sum_{n=1}^{N} z_n b_{kn} \ge b_{k0} - \tau_k, \quad k = 1, 2, \ldots, K, \\ & z_n \ge 0, \quad \beta_j \ge 0, \tau_k \ge 0, n = 1, 2, \ldots, N, \end{aligned} \tag{3}$$

where β represents the slack variable of good outputs and τ stands for the slack variable of bad outputs. What needs to be emphasized is that radial and nonradial models have been combined in a unified framework by Tone and Tsutsui [27], which is the epsilon-based measure (EBM) model. Employing the concept and method of the Malmquist–Luenberger index by Chung et al. [28], the EBM-ML DEA model is defined. Table 1 presents the input and output variables of TFP measurement. It should be pointed out that the calculation of the capital factor is done by referring to the research of Li and Wu [4] and adopting the perpetual inventory method. The energy factor inputs are the weight summation of coal, coke, crude oil, kerosene, fuel oil, gasoline, diesel, and natural gas consumption according to the conversion coefficients of standard coal supplied by China Statistical Yearbook. All the data are derived from China Statistical Yearbook, China Environment Yearbook, China Energy Statistical Yearbook, and provincial statistical yearbook.

Figure 1 illustrates the average TFP of each region in 2006–2016 after the measurement, and it can be found that the TFP in each region presents significant regional differences. The TFP of Jiangsu, Zhejiang, Shandong, Beijing, Shanghai, Tianjin, Guangdong, Chongqing, Liaoning, and other areas is higher and greater than 1. Most of these provinces belong to the southeast coast and municipalities. Because the above areas benefit from a large number of foreign direct investment and administrative attributes, the use of resource factors and the attraction of talents have significant policy advantages, regional advantages, and national orientation. The TFP of central and western provinces of Shanxi, Jilin, Heilongjiang, Anhui, Hunan, Guangxi, Yunnan, Gansu, and so on is lower than 0.6, and the rank of these provinces is near the bottom. Mainly because these provinces are limited to the geographical location, weather climate, and relatively large transportation costs, the industrial structure layout is partial to the primary industry and the third industry, and the technology bias is inadequate.

Table 1: Input and output variables.

Variable attribute	Measure index	Measure method	Variable unit
Input factor	Labor force factor	Employment in three industries at the end of the year	10,000 persons
	Capital factor	Cumulative investment in fixed assets of the whole society	100 million yuan
	Energy factor	Converted standard coal consumption	10,000 tons
Desirable output	GDP	GDP measured by the expenditure approach	100 million yuan
Undesirable output	Industrial solid waste	Emission of industrial solid waste	10,000 tons
	Industrial waste water	Emission of industrial waste water	10,000 tons
	Industrial waste gas	Emissions of industrial waste gases such as S02 and smoke dust	10,000 tons

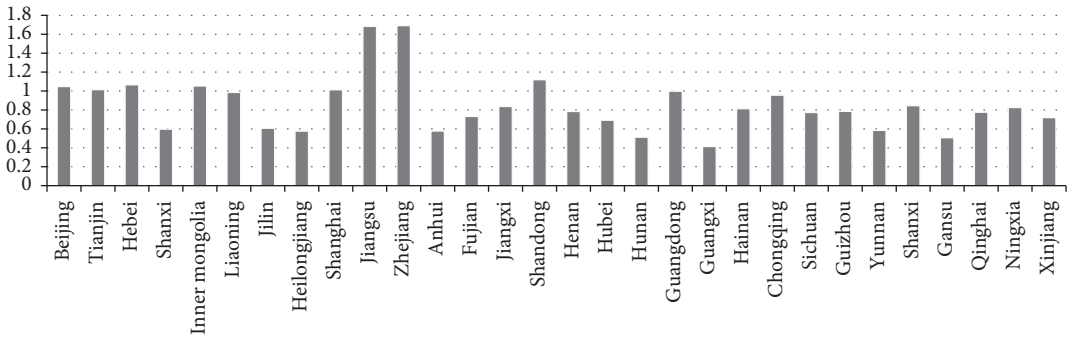

Figure 1: Average TFP (2006–2016).

3.2. Environmental Regulation. The key of this paper is the effective division and measurement of environmental regulation. According to Xie et al. [26], environmental regulation tools are divided into three categories: command-and-control type, market incentive type, and voluntary consciousness type. Command-and-control environmental regulation is performed by the government environmental protection law enforcement agency and legislature. The government sets pollutant emission standards for enterprises and gives administrative punishment. As for the measure method, it can be calculated by executive manpower investment of the environmental protection agency, the number of cases handled by the environment protection agency, and the number of governance proposals accepted by the environmental protection agency. Market incentive environmental regulation means that government departments use market means such as price and cost to reduce the environmental pollution level by encouraging green technological innovation, and marketability is the main characteristic. China's market incentive environmental regulation mainly includes pollution levy, financial subsidies, and tradable emission permits. Because of data availability and integrity, it is represented by the proportion of the total pollution levy in GDP. Voluntary conscious environmental regulation mainly refers to the behavior and commitment of social individuals and enterprises to participate actively in environmental protection and emission reduction. Voluntary is its main characteristic. The voluntary conscious environmental regulation is mostly embodied in the participation of social and personal environmental protection. Compared with environmental protection, enterprises incline to the maximum economic benefits. In this paper, it is measured by the total number of environmental letters, calls, and networks per 1000 people. Table 2 provides the specific classification, measurement indicators, and units of environmental regulation, and the data are derived from China Environment Yearbook.

Figure 2 shows the average value command-and-control environment regulation in different regions during 2006–2016, and the difference in regional regulation is significant. The regulation intensity of Liaoning, Guangdong, Zhejiang, Hebei, Jiangsu, Shandong, Henan, Shanxi, Sichuan, Beijing, Heilongjiang, and other areas achieves a high ranking. Because of the relatively high proportion of industries in these areas, the environmental pollution emissions are greater. And Beijing belongs to the national administrative center, so the demand for high environmental quality is strong. The regulatory intensity of Hainan, Qinghai, and Ningxia is ranked back, and the main reason is the influence of the geographical location and industrial structure layout. Hainan has a low latitude and is surrounded by the sea, where the development of the tourism industry is easy, whereas other industries are relatively low. The topography and climate of Qinghai and Ningxia decide that they are suitable for the development of nomadism and tourism. The above three areas do not need stronger command-and-control regulation.

Figure 3 shows the mean value of market incentive environmental regulation in different regions during 2006–2016, and the difference between regions is obvious. According to Figure 2, pollution discharge levy accounts for more than 10% of GDP in Shanxi, Guizhou, Ningxia, and

Table 2: Classification and measurement of environmental regulation.

Classification standard	First-level index	Measurement index	Unit
Command-and-control environmental regulation	The human input of environmental agencies	The number of people at all levels of the regional environmental protection system at the end of the year	Person
	Number of environmental protection cases handled by environmental protection organizations	Environmental administrative punishment cases accepted	Case
	Opinions and suggestions on environmental protection administration accepted by environmental protection organizations	Number of environmental proposals accepted during the two sessions	Proposal
	Implementation of environmental impact assessment of enterprise investment projects from environmental protection institutions	Implementation rate of the environmental impact assessment system	%
Market incentive environmental regulation	Environmental incentive intensity under the market function	The proportion of the total collection of pollution charges in GDP	%
Voluntary conscious environmental regulation	Input intensity of active promotion of environmental protection	The total number of letters and calls (telephone and network) per 1000 people	Pieces/1000 persons

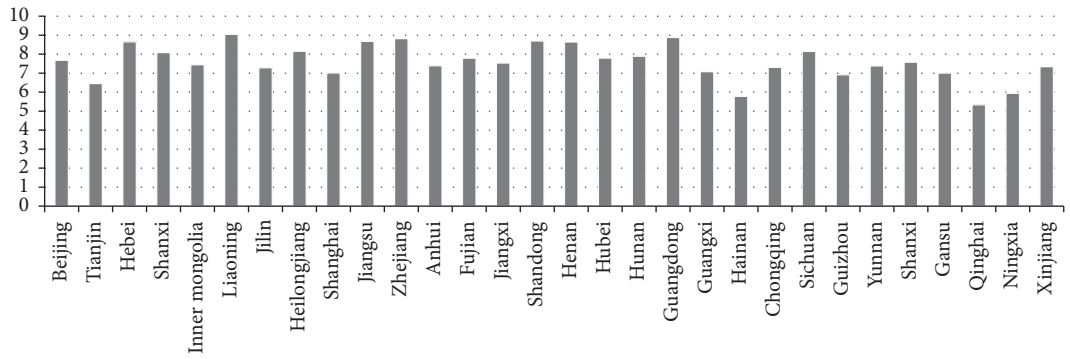

Figure 2: The average value of command-and-control environmental regulation (2006–2016).

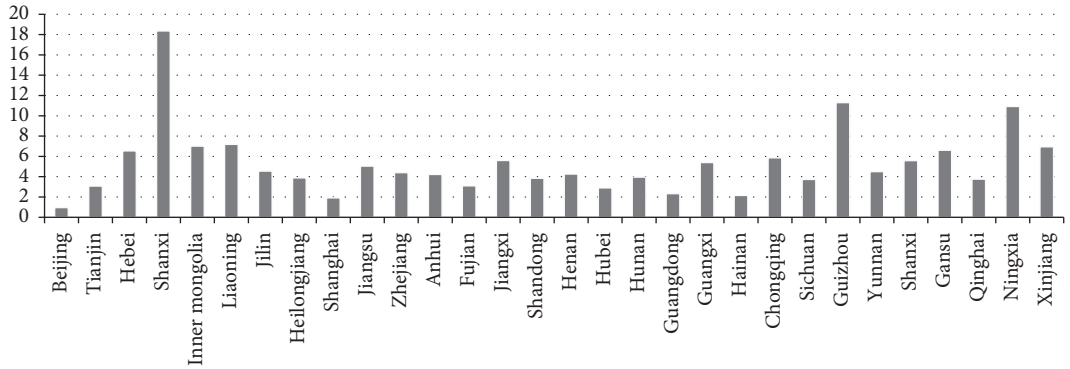

Figure 3: The average value of market incentive environmental regulation (2006–2016).

other regions. The proportion reached over 6% in Liaoning, Xinjiang, Inner Mongolia, Hebei, and Gansu, and over 4% in Jilin, Jiangsu, Zhejiang, Anhui, Jiangxi, Henan, Guangxi, Chongqing, Yunnan, and Shaanxi. The proportion is less than 4% only in Beijing, Tianjin, Heilongjiang, Shanghai, Fujian, Shandong, Hubei, Hunan, Guangdong, and Hainan. And, it is below 2% in Beijing, Shanghai, and Hainan. The main reason is the difference of industrial structure, production technology, and clean technology. The industrial technology in Shanxi, Guizhou, and Ningxia lags far behind

that in Beijing, Shanghai, and other areas, and heavy consumption of per unit GDP results in a larger amount of pollution charge levy of per unit GDP.

Figure 4 provides the average value of voluntary conscious environmental regulation in different regions in 2006–2016, and the regional differences are significant. The voluntary conscious environmental regulation in four municipalities, namely, Shanghai, Chongqing, Tianjin, and Beijing, is much stronger than that in other provinces because the above-mentioned areas undertake the functional missions such as the national economic development and cultural heritage. The administrative level of these areas is the same as province, and the state gives greater preferential policies to promote its rapid development, to radiate the surrounding economy, and to balance regional economic development. In terms of provinces, the number of letters, phone calls, and Internet mails per 1000 people is more than 6 in Jiangsu, Zhejiang, Guangdong, Fujian, Ningxia, Guangxi, Shanxi, and Liaoning, while that in other areas is relatively low. Because of the regional economic development differences, low-income groups are more concerned about income levels compared to environmental protection. Once material needs are met, letters and calls about environmental protection will be significantly increased.

4. Threshold Effect Mechanism Analysis of Environmental Regulation on TFP

Before analyzing the threshold effect of environmental regulation on the total factor productivity, it is necessary to understand the process of environmental regulation for enterprises from government and society. The drain contamination of the enterprise leads to water pollution, air pollution, and solid waste accumulation, which directly shows the deterioration of the environmental quality and residents' health. In order to improve the quality of the environment, government and society will formulate pollutant emission standards according to industry development and pollutants' nature. Once the sewage is not up to the standard, the enterprise needs to be closed, merged, or transferred. To ensure the continued production, these enterprises need to introduce advanced production equipment and pollutant cleaning equipment and increase technical research expenses. It will lead to difficult cash flow and lower profitability. According to the strong Porter hypothesis, advanced production equipment will produce some innovative compensation effects to offset additional cost expenditure caused by environmental regulations. But it does not consider heterogeneity of enterprise production. For small and medium enterprises, once the purchase of the equipment results in a long cycle of debugging, the enterprise capital chain will be broken. It will not be able to buy production technology and eventually lead to the enterprise shutdown. Thus, solving the problem of enterprise funds becomes the key to realization of the strong Porter hypothesis. From the actual situation of China, the fund problem in the process of environmental regulation can be solved through the following two channels.

(i) Opening to the outside world and lowering threshold for foreign investment industries and funds: utilizing positive technology spillover and advanced management experience of foreign direct investment raises the technology level of the enterprise, reduces the unit energy consumption of the enterprise, and achieves the discharge standard. Relatively cheap Chinese labor provided and relatively advanced foreign production and clean technology will greatly reduce the expenditure of the purchasing equipment caused by enterprise environmental regulation. Enterprises can sustain production, and the compensation effect of innovation in the strong Porter hypothesis can be realized in the short run. With the positive effects of FDI in a certain area, significant spatial demonstration effects and competitive effects will emerge and will gradually increase with the promotion of the level of information technology. Moreover, because of the unique political and economic management system of China, the free trade development between regions will rapidly improve. FDI quota and industry category of the region will increase considerably. The correlation between the government and the enterprise will be close, which is not conducive to enhancing the environmental regulation by environmental protection institutions.

(ii) Reducing the cost of corporate finance and increasing the supply of loan funds provided by financial institutions: when the size of the financial market is small and the market demand is in the rising stage, the borrowing cost of the enterprise is relatively high, so it is difficult for the enterprise to make a successful financing. With the expansion of the financial market scale, especially the marketization of the deposit and loan interest rate, the market competition will be more and more fierce and the enterprise financing cost will decline, which will increase the possibility of solving the funding problems caused by regulation. Commercial bank is the subject of financial institutions in China. In the early stage, it mainly included five state-owned banks, small- or medium-sized joint-stock banks, and the monopoly of the banking industry is remarkable. The profit business mainly depends on the interest margin income, while the business of small- and medium-sized enterprises was relatively small. With the reform of banking market supervision and system, the city commercial banks and village banks began to build up gradually. It deserves to be mentioned that the internet finance corporation was established with the promotion of the Internet information level and the gradual liberalization of banking licenses. Thus, the fund supply for enterprise credit demand caused by environmental regulation is increasing.

One of the cores of this paper is to analyze the threshold effect of voluntary conscious environmental regulation on

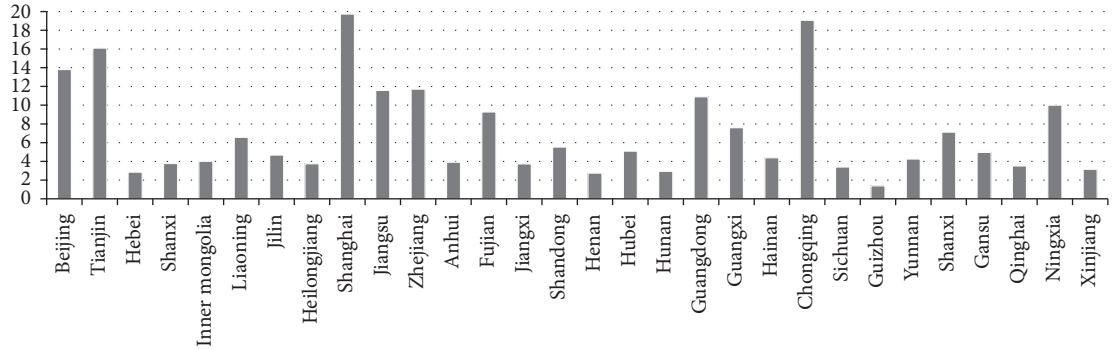

Figure 4: The average value of voluntary environmental regulation (2006–2016).

the TFP, which emphasizes the intensity of environmental protection consciousness. The regional human capital level has a great influence on the environmental protection consciousness. When the level of human capital is relatively low, economic thinking and legal thinking are not comprehensive. Lower awareness of environmental protection will cause great obstacles to the environmental law enforcement of the government and society, which will lead to the increase of regulation costs. With the improvement of the education level in various regions, the awareness of personal environmental protection has increased. The amount and intensity of environmental protection activities have increased, which is conducive to promoting the regional environmental protection and TFP. The above situation also exists in command-and-control-type and market-based-type environmental regulation. Based on the above analysis, this paper proposed the following hypothesis.

4.1. Hypothesis. The impact of environmental regulation on the total factor productivity has a threshold conversion characteristic of foreign direct investment (financial scale or human capital). With the rise of FDI intensity (financial scale or human capital), the influence effect of environmental regulation may change, but different regulatory tools may show different regulatory effects.

5. Empirical Analysis

5.1. Model Construction and Variable Specification. The purpose of this paper is to analyze the threshold effect of different types of environmental regulations on the total factor productivity. Therefore, the panel threshold model of Hansen [34] is adopted. In this model, the threshold variables are foreign direct investment and the scale of financial and human capital; the key variables are the command-and-control regulation, market-based environment incentive environmental regulation, and voluntary consciousness environmental regulation; and the explanatory variable is the TFP. Scholars point out that the industrial structure, technological R&D intensity, and land finance have a certain impact on the total factor productivity. In this paper, the three variables and two interactions between some controls and regulations are included in the model as control variables [35–37]. In order to reduce the volatility of the variable data, the data are processed by natural logarithms, and the following econometric models are obtained:

$$\begin{aligned}\mathrm{LnTFP}_{it} &= \alpha_1 \mathrm{LnCER}_{it} I\left(q_{it} \le \gamma_1\right) + \alpha_2 \mathrm{LnCER}_{it} I\left(\gamma_1 \le q_{it} \le \gamma_2\right) \\ &\quad + \cdots + \alpha_n \mathrm{LnCER}_{it} I\left(\gamma_{n-1} \le q_{it} \le \gamma_n\right) + \alpha_{n+1} \mathrm{LnSTR}_{it} \\ &\quad + \alpha_{n+2} \mathrm{LnRD}_{it} + \alpha_{n+3} \mathrm{LnRFIN}_{it} + \alpha_{n+4} \mathrm{LnCER}_{it} \\ &\quad \times \mathrm{LnSTR}_{it} + \varepsilon_{it},\end{aligned} \tag{4}$$

$$\begin{aligned}\mathrm{LnTFP}_{it} &= \beta_1 \mathrm{LnHER}_{it} I\left(q_{it} \le \gamma_1\right) + \beta_2 \mathrm{LnHER}_{it} I\left(\gamma_1 \le q_{it} \le \gamma_2\right) \\ &\quad + \cdots + \beta_n \mathrm{LnHER}_{it} I\left(\gamma_{n-1} \le q_{it} \le \gamma_n\right) + \beta_{n+1} \mathrm{LnSTR}_{it} \\ &\quad + \beta_{n+2} \mathrm{LnRD}_{it} + \beta_{n+3} \mathrm{LnRFIN}_{it} + \beta_{n+4} \mathrm{LnHER}_{it} \\ &\quad \times \mathrm{LnSTR}_{it} + \kappa_{it},\end{aligned} \tag{5}$$

$$\begin{aligned}\mathrm{LnTFP}_{it} &= \chi_1 \mathrm{LnVER}_{it} I\left(q_{it} \le \gamma_1\right) + \chi_2 \mathrm{LnVER}_{it} I\left(\gamma_1 \le q_{it} \le \gamma_2\right) \\ &\quad + \cdots + \chi_n \mathrm{LnVER}_{it} I\left(\gamma_{n-1} \le q_{it} \le \gamma_n\right) + \chi_{n+1} \mathrm{LnSTR}_{it} \\ &\quad + \chi_{n+2} \mathrm{LnRD}_{it} + \chi_{n+3} \mathrm{LnRFIN}_{it} + \nu_{it},\end{aligned} \tag{6}$$

where TFP represents the total factor productivity, CER indicates the command-and-control environmental regulation, HER is the market incentive environmental regulation, VER represents a voluntary consciousness type of environmental regulation, $I(q_{it})$ is the indicator function, and γ_i represents the threshold variable, including foreign direct investment (FDI), financial scale (FIN), and human capital level (HUM). STR stands for the industrial structure, RD is the technological R&D intensity, and RFIN indicates the land finance.

The measurement of the total factor productivity and environmental regulation has been illustrated in Section 3, and the measurement of HUM is done by referring to the method of Li and Wu [4]; FDI is the ratio of the converted amount of actual foreign investment and the average annual exchange rate in each region to the regional GDP, FIN is represented by the ratio of the total deposits and loans of regional financial institutions at the end of the year to the regional GDP, STR is represented by the proportion of the regional second industrial output value to the regional GDP, RD is represented by the ratio of the regional

technology R&D expenditure to the regional GDP, and RFIN is the proportion of regional land government receipts to the regional GDP. The data are derived from China Statistical Yearbook, China Financial Yearbook, China Statistical Yearbook on Science and Technology, and statistical yearbook of provinces. Table 3 illustrates the descriptive statistics of all variables. It can be found that there is a certain volatility in the data, which indicates that the regional differences are great and confirms the rationality of the panel model.

Table 3: Descriptive statistics of variables.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
TFP	330	0.8993	0.4651	0.2677	4.0199
CER	330	3051.3230	3098.0430	153.3465	21040.9900
HER	330	5.4907	4.9187	0.1589	47.6962
VER	330	28377.6222	30159.0334	55.0000	214055.0000
HUM	330	8.6756	1.0074	6.3778	12.0650
FDI	330	2.4968	1.9238	0.0683	8.1914
FIN	330	2.6512	1.0183	1.2882	7.4898
STR	330	48.0251	7.6769	21.3000	61.5000
RD	330	1.3098	1.0193	0.1736	6.0800
RFIN	330	0.4963	0.2549	0.0289	1.7047

5.2. Empirical Research. Before threshold model regression, the threshold number is required to be tested. The test is applied in the order of no threshold, single threshold, and double thresholds. The null hypothesis is that the inexistence of a threshold, the existence of preparation hypothesis have one threshold. Table 4 shows the F statistic values and P values of the threshold number test of HUM, FDI, and FIN in the models (4)–(6). It is found that the impact of command-and-control environmental regulation on the TFP has two threshold variables, namely, LnFDI_CER and LnFIN_CER, and the threshold number is 1. The impact of market incentive environmental regulation on the TFP has two threshold variables, namely, LnFDI_HER and LnFIN_HER, and the threshold number is 1. The impact of voluntary consciousness environmental regulation on the TFP has a threshold variable, namely, LnHUM_VER, and the threshold number is 1. Table 5 shows the threshold values and the confidence interval at the 95% level of the above five threshold variables under the corresponding threshold model.*Note.* ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Table 4: Test of the threshold number.

Number of thresholds	Single-threshold test		Double-threshold test	
Variable	F value	P value	F value	P value
LnHUM_CER	6.2009	0.7239	5.7638	0.4099
LnFDI_CER	11.5065***	0.0010	6.8572	0.1372
LnFIN_CER	10.8875**	0.0180	7.4002	0.1269
LnHUM_HER	4.7482	0.8022	3.6372	0.8686
LnFDI_HER	23.9921**	0.0192	10.3323	0.2077
LnFIN_HER	19.8430*	0.0971	9.5211	0.3493
LnHUM_VER	21.9506*	0.0417	12.9106	0.1001
LnFDI_VER	5.0145	0.3420	3.5217	0.6014
LnFIN_VER	4.6089	0.1021	2.9403	0.3027

Table 6 shows the threshold regression results of the impact of command-and-control environmental regulation on the TFP. Table 7 shows the threshold regression results of market incentive environmental regulation affecting the TFP. It is found that the threshold effect of FDI, the threshold effect of FIN, and the influence of controlled variables remain highly consistent under the two different types of environmental regulation models, and there is only difference in the significance level and influence degree. When LnFDI_CER < 1.2610 or LnFDI_HER < 1.0063, a moderate government environmental regulation is conducive to increasing the regional TFP, and the latter one passes the hypothesis test at the level of significance of 5%. But the former does not pass the significance test. After crossing the threshold value, that is, LnFDI_CER > 1.2610 or LnFDI_HER > 1.0063, the environmental regulation will lead to the reduction of the TFP. Both of the command-and-control environmental regulation and market incentive environmental regulation have cost effect. In the short term, the small- and medium-sized enterprises are unable to introduce technology and innovate, while the large enterprises can continue to produce after paying the fine or appropriate rectification, which will lead to weak market competitiveness and increased degree of monopoly in the industry. The entry of the foreign capital leads to increased competition in the market and breaking of the original industry equilibrium pattern, and the cash flow difficulties of small- and medium-sized enterprises can be solved. Large enterprises are worried about market share becoming lower, so they have to improve their production cleaning technology and management experience, which will be beneficial to the promotion of the TFP.

The threshold effect of financial scale is opposite to the threshold effect of FDI. When LnFIN_CER < 0.4971 or LnFIN_HER < 1.0337, the coefficients of LnCER and LnHER are −0.0674 and −0.0633, respectively, and both pass the hypothesis test at the significance level of 10%. It shows that, below the threshold value, 1% increase in LnCER and LnHER will cause a 0.0674% or 0.0633% reduction in the TFP. When the threshold value is exceeded, that is, LnFIN_CER > 0.4971 or LnFIN_HER > 1.0337, the coefficients of LnCER and LnHER change from negative to positive, and the values are, respectively, 0.0390 and 0.0234; however, only the latter one passes the hypothesis test at the significance level of 10%. The main reason is that when FIN is smaller, the financial institutions are less, the financial industry monopoly is obvious, and the allocation of capital factors tends to state-owned enterprises. And once the government implemented environmental regulation to sewage enterprises, enterprise capital demand will surge, financial institutions will increase financial interest on loans, and the financing costs and probability of small- and medium-sized enterprises will be increased; therefore, the innovation compensation effect mentioned in the strong Porter hypothesis cannot be realized. The main reason for this situation is that the financial market scale is small and

Table 5: Threshold values and 95% confidence intervals of threshold variables.

Threshold variable	LnFDI_CER	LnFIN_CER	LnFDI_HER	LnFIN_HER	LnHUM_VER
Value of the threshold	1.2610	0.4971	1.0063	1.0337	2.2751
Confidence interval	[0.9805, 1.5508]	[0.4983, 0.5344]	[0.9475, 1.0308]	[1.0271, 1.0396]	[2.2704, 2.2923]

Table 6: Impact of command-and-control environmental regulation on the TFP.

Model 1	Coefficients	Model 2	Coefficients
LnFDI_CER < 1.2610	0.0452 (1.3245)	LnFIN_CER < 0.4971	−0.0674* (−1.9001)
LnFDI_CER > 1.2610	−0.0657* (−1.8665)	LnFIN_CER > 0.4971	0.0390 (1.1289)
LnSTR	0.1377** (2.0056)	LnSTR	0.0155** (2.0944)
LnRD	0.0640* (1.8550)	LnRD	0.0871** (2.2240)
LnRFIN	−0.0621*** (−3.7404)	LnRFIN	−0.0563* (−1.7925)
LnCER × LnSTR	0.0012** (2.1020)	LnCER × LnSTR	0.0009*** (3.2010)
Number of bootstraps	2000	Number of bootstraps	2000

Note. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively; t values are shown in parentheses.

Table 7: Impact of market incentive environmental regulation on the TFP.

Model 3	Coefficients	Model 4	Coefficients
LnFDI_HER < 1.0063	0.1151*** (2.9793)	LnFIN_HER < 1.0337	−0.0633** (−2.1110)
LnFDI_HER > 1.0063	−0.0401 (−1.0016)	LnFIN_HER > 1.0337	0.0234* (1.8214)
LnSTR	0.2370 (1.4877)	LnSTR	0.0492 (1.5538)
LnRD	0.1102* (1.7709)	LnRD	0.2201*** (3.3378)
LnRFIN	−0.0740*** (−2.9112)	LnRFIN	−0.0220 (−0.7221)
LnHER × LnRD	0.0074** (2.0095)	LnHER × LnRD	0.0088*** (4.5018)
Number of bootstraps	2000	Number of bootstraps	2000

Note. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively; t values are shown in parentheses.

the competition is low, and the supply of financial capital is far less than the demand. With the reform of financial market and the implementation of the shareholding system of state-owned banks, rural credit cooperatives turn into city commercial banks and rural banks, coupled with the emergence of Internet banking. The circulation of financial information is unimpeded, the ratio of capital factor supply and demand is raised remarkably, the financing cost of the enterprise is reduced, and the innovation compensation effect of the strong Porter hypothesis is realized.

About control variables, the coefficients of LnSTR are positive in models 1–4. However, hypothesis tests with a significance level of 5% are only passed in model 1 and model 2. It suggests that moderate promotion and maintaining the industrialization rate are beneficial to the growth of the TFP, but it does not mean that the rate of industrialization can continue to rise. The coefficients of LnRD are positive in models 1–4, and all the hypothesis tests with a significance level of 10% are passed. Specifically, when productivity increases by 1%, the total factor productivity could rise by 0.0640%, 0.0871%, 0.1102%, or 0.2201%. The improvement of technological R&D intensity can greatly promote capital investment, personnel training, and innovation potential, effectively shorten the technological R&D cycle, and enhance the total factor productivity. The coefficients of LnRFIN are negative in models 1–4, the values are, respectively, −0.0621, −0.0563, −0.0740, and −0.0220, and the first three models pass the hypothesis tests with a significance level of 10%. It indicates that the rising dependence degree on land finance from the regional government revenue is not conducive to the regional productivity level. Because land revenue is a model of overdraft on future government revenues, it reduces the potential of regional sustainable development. The coefficients of LnCER × LnSTR in model 1 and model 2 are 0.0012 and 0.0009, and the coefficients of LnHER × LnRD in model 3 and model 4 are 0.0074 and 0.0088. Both of the above results are significant at the 5% significance level, which means that environmental regulation can promote the total factor productivity by adjusting the industrial structure and promoting technological research and development.

Table 8 shows the threshold regression effect of voluntary conscious environmental regulation affecting the total factor productivity. It can be found that the impact of control variables on the TFP is consistent with the estimates in Tables 6 and 7. About threshold variables, LnHUM does not exceed the threshold value; that is, when LnHUM_VER < 2.2751, the regulation measures imposed by social residents and environmental protection organizations on the emission behavior of enterprises cannot promote the improvement of the TFP. When LnHUM_VER > 2.2751, moderate promotion of the participation of social residents and environmental protection institutions in environmental regulation will significantly enhance the regional TFP. With the LnVER increase by 1%, the TFP will rise by 0.0247%.

Table 8: Impact of voluntary consciousness environmental regulation on the TFP.

Model 5	Coefficients
LnHUM_VER < 2.2751	−0.0114 (−0.9934)
LnHUM_VER > 2.2751	0.0247* (1.7328)
LnSTR	0.0817** (2.1395)
LnRD	0.0939* (1.7211)
LnRFIN	−0.0489* (−1.7805)
Number of bootstraps	2000

Note. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively; t values are shown in parentheses.

6. Conclusions and Policy Recommendations

6.1. Conclusions. Analysis of the internal relationship between environmental regulation and the total factor productivity is the way to promote the TFP. Based on the provincial panel data of 2006–2016, this paper divides the environmental regulation into three types: command-and-control type, market incentive type, and voluntary consciousness type, and constructs the panel threshold model by using foreign direct investment, financial scale, and human capital level as the threshold variables to explore the threshold effect of environmental regulation affecting the TFP. The results show that the impact of command-and-control environmental regulation and market incentive environmental regulation on the total factor productivity is limited by the single threshold of foreign direct investment and financial scale, while the impact of the voluntary consciousness environment regulation on the TFP is limited by the single threshold of human capital. When LnFDI_CER < 1.2610 or LnFDI_HER < 1.0063 or LnFIN_CER > 0.4971 or LnFIN_HER > 1.0337 or LnHUM_VER > 2.2751, moderate promotion of the intensity of command-and-control environmental regulation, market incentive environment regulation, or voluntary conscious environmental regulation is beneficial to the improvement of the regional TFP. It is also found that the development of the second industry and technological R&D are conducive to the promotion of the total factor productivity, while the increase in the amount of land finance will inhibit the TFP. Based on the above research conclusions, the following policy recommendations are put forward.

6.2. Policy Recommendations. The research shows that gaining some direct investment from foreign merchant and improving the financial scale and the level of human capital are good for avoiding and solving the contradiction between environmental regulation and the total factor productivity and improving the regional TFP when promoting the implementation of environmental regulations. Firstly, government should attract investment based on the local area's enlightenment level, the industrial layout, and the economic development. Especially for foreign enterprise setting, government can give them appropriate privilege on 2 sides: local tax and industrial estate. Secondly, government should deepen the reform of the financial system and strengthen the vitality and competitiveness. Central and local governments should establish the information-sharing system, coordinate and unify action, give the right to the local government step by step, promote the establishment of the local area's financial institution, and weaken the monopoly of the state-owned financial magnate when supervising the authorities. Take financial institution itself as an example; it should strengthen the research and development of a series of financial businesses, such as financial derivatives, and increase the supply with the physical enterprise's loan transaction. Thirdly, the fiscal expenditure on education has to be increased and the level of manpower has to be improved comprehensively. Basic education is the key to improving the educational level, so fiscal expenditure should emphasize on promoting preschool education, elementary education, and junior education, while high school education, vocational education, and higher education can combine alumni resources. Regionally, the transmission of educational equality should be increased, and developed areas should help underdeveloped areas' development of education.

It also indicates that the expenditure on the development of industry and technology research is good for the increase of the TFP, while land finance restrains the increase of the TFP. Firstly, when managing the industrial layout, government should concentrate on introducing secondary industry, but not too much, and government should combine it with primary industry and tertiary industry and make them develop in a balance and have a reasonable layout. Secondly, the government should pay attention to the construction of the technology research level, including the scientific research infrastructure, scientific research personnel training, and interaction of domestic and international research projects. In this way, it can effectively stimulate the enthusiasm for innovation and research and enhance the overall innovation potential and ability of the country. Thirdly, the regional industrial interaction has to be strengthened and the urban layout and industrial development have to be rationally arranged to lower local government revenue's independence on land revenue. The flow of population, labor force value, and labor force structure are the main factors affecting the regional industrial layout; the information sharing between regions should be strengthened, and city's arrangement on scale and development plan should be based on the actual labor supply, so as to promote regional industrial development.

Despite the above contributions, this study also has limitations. As for the measure method of the total factor productivity, the use of a second-stage regression based on DEA results is well known to present statistical problems [38]. Furthermore, China is a big developing country, and its total factor productivity may have regional disparity. Thus, the future study will carry out more precise analysis based on second-stage DEA regression taking the heterogeneity into account.

Data Availability

(1) The total factor productivity used to support the findings of this study has been deposited in the CNKI (China

National Knowledge Infrastructure) repository, and the DOI of the reference paper is 10.1016/j.jclepro.2016.10.042. In addition, the basic data to measure the urban-rural income gap may be released upon application to China's National Bureau of Statistics or EPS database. (2) The environmental regulation used to support the findings of this study has been deposited in the CNKI (China National Knowledge Infrastructure) repository, and the DOI of the corresponding reference paper is 10.1016/j.ecolecon.2016.10.019. In addition, the data used to measure financial agglomeration for supporting the findings of this study may be released upon application to China's National Bureau of Statistics or EPS database.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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