The Influence of Environmental Regulation on Industrial Green Total Factor Productivity Based on GIS System.

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Abstract: This paper is based on the big data background and combined with the corresponding data model to study the existing problems. Firstly, this paper combs the relationship between environmental regulation and green total factor productivity from the theoretical level. Secondly, taking the panel data of 30 provinces in China from 2004 to 2019 as samples, the average regional concentration of high energy consuming industries in each province is drawn by using ArcGIS software, and the national sample is divided into undertaking and transferring out areas of high energy consuming industries according to the changes in 2004 and 2019. Finally, the threshold regression model is established with Stata software to verify whether there is a technology density threshold for environmental regulation on industrial green total factor productivity. It is found that environmental regulation has a threshold effect on industrial green total factor productivity, and there is an optimal range of technology density.

Keywords: Environmental regulation; GIS system; Green total factor productivity; Technical density; Stata

1 Introduction

With science and technology growing rapidly, the Internet has brought us may convenience. Cloud computing and big data analysis are more involved in scientific research, which not only saves a lot of time, but also makes scientific research results more reliable.

Environmental regulation means that because environmental pollution has negative externalities, the government and public institutions formulate relevant policies and methods through the process, and implement direct and indirect regulatory means to restrict and interfere with enterprises and consumers, so as to internalize environmental costs, so as to achieve economic benefits and environmental protection, so as to achieve "win-win" [9]. Total factor productivity (TFP) refers to the part of output growth rate exceeding factor input growth rate, that is, the part of economic growth that cannot be explained by factor input growth. It reflects the quality of economic growth [6]. In recent years, due to the increasingly serious problem of resource scarcity, green total factor productivity (GTFP), which includes energy consumption

ICIDC 2022, June 17-19, Qingdao, People's Republic of China

DOI 10.4108/eai.17-6-2022.2322714

and carbon dioxide emissions into the green growth analysis model, is favored by most scholars. Green total factor productivity not only takes into account the reduction of the loss of high carbon energy, but also shows the current demand for carbon emission reduction, and can more comprehensively measure the quality of industrial green development.

2 Theoretical analysis and research hypothesis

The impact of environmental regulation on industrial green total factor productivity has both negative "crowding out effect" and positive "compensation effect" [8].

The reason for this divergence lies in whether environmental regulations provide incentives for enterprises to achieve green technological progress. The magnitude of the innovation compensation effect caused by appropriate environmental design in the "Porter Hypothesis" will determine the nature of the impact of environmental regulations on industrial green total factor productivity. As one of the industrial characteristics, technology density is closely related to technological innovation [1]. It can be said that the higher the technology density of an enterprise, the greater the innovation space and capability it has. Under the relatively loose environmental regulation standards, there will be no great difference in the sensitivity of high-tech enterprises and low-tech enterprises to the intensity of environmental regulation. However, once the environmental regulation standards are improved, low-tech enterprises will face the danger of shutdown because they are difficult to meet the established environmental standards. It can be seen that only when the technology density of a region reaches a certain threshold, can environmental regulation have a positive impact on industrial green total factor productivity. Based on the above analysis, the following assumptions are put forward.

H1: The impact direction of environmental regulation on industrial green total factor productivity is uncertain. When the "compensation effect" is more than the "crowding out effect", environmental regulation promotes the green total factor productivity of the industry. On the contrary, it plays a inhibitory role.

H2: The innovation compensation effect of environmental regulation is related to the technology density of the region. The impact of environmental regulation on industrial green total factor productivity has a threshold effect.

3 Model design and data description

The level of technology in a region determines the size of innovation compensation effect. Therefore, taking technology density as the threshold variable, this paper investigates the impact of environmental regulation on industrial green total factor productivity under different technology densities. The specific model is set as follows. A good study of the above problems is of enlightening significance to solve how to achieve sustainable development through technological channels in the undertaking areas of high energy consuming industries. Next, we will build a threshold regression model for empirical test.

3.1 Threshold Model Design

The panel threshold model was originally proposed by [4]. The model divides intervals according to the characteristics of the data itself, and uses threshold variables to determine the distinguishing points, which can solve the problems of interval simplification and subjective conjecture model [2]. The threshold regression model is shown below.

$$GTFP_{it} = \alpha_0 + \alpha_1 ER_{it} \cdot I(TE \leq \gamma_1) + \alpha_2 ER_{it} \cdot I(TE \geq \gamma_1) + \beta_1 X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Where I(·) is an indicative function, γ is the threshold value, $\mu_i$is individual effect, ε_{it} is a random error term. Where i is the province and t is the year. The explained variable is GTFP, and the core explanatory variable is ER.$X_{it}$is the control variable.

3.2 Variable and Data Description

Green Total Factor Productivity: The global Malmquist Luenberger index (GML) for global reference is transitive and has no problem of VRS without feasible solution, which is suitable for cross period comparison. GML index can be divided into GEF (technical efficiency change index) and GTC (technical progress change index) [3]. GML index measures the change of green total factor productivity (GTFP) from t to t+1. The base period is set to 1, and the green total factor productivity (GTFP) of any research year can be obtained by cumulative multiplication.

Labor input. Select the average number of industrial workers in each province as the labor input.

Capital input. The calculation of capital stock adopts the perpetual inventory method.

Energy consumption. According to the data released by China carbon accounting database (CEADS), the industrial consumption of eight major energy varieties is converted into standard coal according to the reference coefficient of energy converted into standard coal published in China energy statistical yearbook.

Expected output. Take the industrial output value of each province as the expected output. Taking 2004 as the base period, the output value is adjusted by the ex factory price index of industrial producers in each province to eliminate the impact of inflation.

Unexpected output. Calculate the industrial CO2 emissions according to the data published by China carbon accounting database (CEADS).

Environmental Regulation: This paper refers to the index construction methods of Xiaosheng Li (2022) and Gang Du (2018), and makes adjustments to adapt to the research purpose of this paper. [3] [10]

Transfer of High Energy Consuming Industries: The average concentration of regional industries is calculated by referring to lichunmei's practice. Taking 2004-2019 as the research range, the provinces with increased regional average concentration of high energy consuming industries are the industrial undertaking areas, otherwise they are the industrial transfer out areas. See Table 1 for specific results. Using ArcGIS 10.0 software, the average regional concentration of China's high energy consuming industries in 2004 and 2019 are plotted respectively. See Figure 1 and 2 for specific results.

Control Variable: For the selection of control variables, refer to the articles of Min Fan (2022) and Shijin Wang (2021) [5] [7].

Table 1: Transfer out and undertaking places of high energy consuming industries.

Industrial transfer out area	Beijing, Tianjin, Shanxi, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Guangdong and Gansu
Industrial undertaking place	Hebei, Inner Mongolia, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Qinghai, Ningxia and Xinjiang

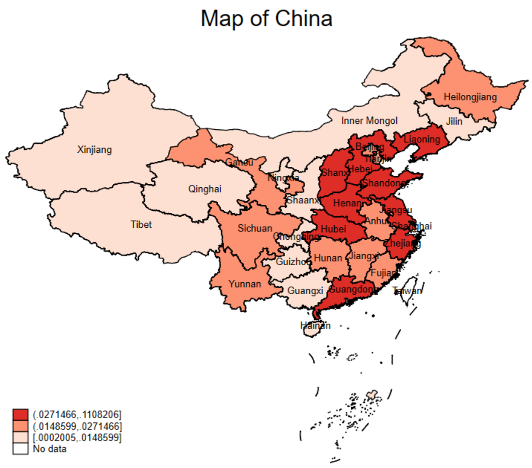

Figure 1: Average regional concentration of high energy consuming industries in 2004.

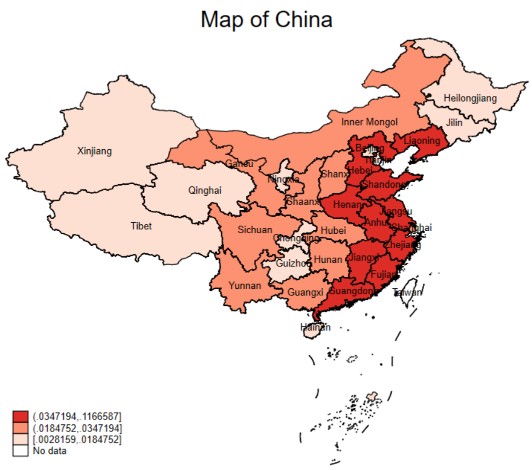

Figure 2: Average regional concentration of high energy consuming industries in 2019.

3.3 Data Sources

This paper selects the panel data of 30 provinces in China (except Hong Kong, Macao and Taiwan) from 2004 to 2019, and Tibet is finally excluded due to lack of data. The original data are mainly from China carbon accounting database (CEADS), National Bureau of statistics, EPS database, China Statistical Yearbook, China Industrial statistical yearbook, China Energy Yearbook, China Environmental Statistical Yearbook, China Science and technology statistical yearbook and China economic census yearbook of relevant years. The missing data of some provinces are supplemented by interpolation.

4 Empirical analysis

This paper uses stata15.0 software to test and regression the threshold model. By taking the technology density as the threshold variable, 300 self sampling tests were set up, and the threshold test was carried out in three samples: the country, the transfer out area and the undertaking area of high energy consuming industries. There are two thresholds for the transfer out of high energy consuming industries, the first threshold is 0.0141, and the second threshold is 0.0182; High energy consuming industries have a single threshold effect, with a threshold value of 0.0021.

Table 2: Threshold regression results of the transfer out and receiving areas of the national and high energy consuming industries.

Variable	transfer out area	undertaking place
$\mathrm{ER_{it}} \cdot \mathrm{I}$ $(\mathrm{TE} \le \gamma_1)$	0.12*(0.059)	0.259*(0.0705)
$\mathrm{ER_{it}} \cdot \mathrm{I}$ $(\gamma_1 \le \mathrm{TE} \le \gamma_2)$	7.21***(0.0769)	5.01***(0.0742)
$\mathrm{ER_{it}} \cdot \mathrm{I}$ $(\mathrm{TE} \ge \gamma_2)$	0.0564*(0.00276)	
γ_1	0.0141	0.0021
γ_2	0.0182	
struc	0.522*(0.285)	2.355***(0.518)
IS	0.276*(0.000)	0.0987(0.000)
FDI	2.202***(0.3510)	-0.387*(1.0050)
cons	0.748***(0.102)	0.460**(0.175)

Note: ***, **, * indicate that the level of significance are 1%,5% and 10%, respectively. Figures in parentheses are standard error.

According to the regression results (see Table 2), the nonlinear effect of environmental regulation on industrial GTFP is obvious. In the samples of transfer out areas, the influence coefficients of environmental regulation on industrial GTFP are significantly positive. When the technology density is lower than 0.0141, the coefficient of environmental regulation is 0.12.

When the technology density is between 0.0141~0.0182,the coefficient of environmental regulation is 7.21.When the technology density is higher than 0.0182, the coefficient of environmental regulation is 0.0564.

Secondly, it analyzes the results of the high energy consuming industries. When the technology density is lower than 0.0021, the coefficient of environmental regulation is 0.259. When the technology density is higher than 0.0021, the coefficient of environmental regulation is 5.01. The threshold value is smaller than that of the high energy consuming industries. The reason is that the technology and industrial foundation of the high energy consuming industries are weaker than that of the high energy consuming industries, the economic development is slow, and the corresponding R&D internal expenditure accounts for less. Based on the above analysis, it can be seen that the marginal effect of environmental regulation on industrial GTFP gradually decreases after the regions with high technology density cross a certain threshold. At this time, increasing R&D investment is no longer the best choice, but maintaining the original state will be more conducive to the play of environmental regulation. Areas with low technology density should increase R&D investment and pay attention to the conversion rate of scientific research achievements.

In terms of control variables, the improvement of industrial structure has a significant positive impact on the industrial GTFP of the industrial transfer out and receiving areas, indicating that the proportion of industry in the gross national product should be increased, and the tertiary industry should not be blindly developed. The industrial scale is significantly positive to the industrial GTFP of the transfer out areas at the level of 1%, which can show that increasing the industrial scale helps to improve the industrial GTFP. In terms of FDI, the FDI of the transfer out areas of high energy consuming industries significantly improves the industrial GTFP. For every 1% increase in FDI, GTFP will increase by 2.202%. But the place of undertaking is the opposite. This shows that the transfer out areas of high energy consuming industries have a high level of economic development and sufficient capital. They no longer blindly pursue the quantity of FDI, but pay more attention to the quality of FDI. Therefore, they have effectively improved GTFP. FDI flowing into the high energy consuming industrial undertaking areas is mainly to seek resources, and its core technology is blocked and protected, so there is no effective technology spillover in the undertaking areas.

5 Conclusions and policy recommendation

Formulating reasonable environmental regulation policies is conducive to the promotion of GTFP, which is an important issue in China's industrialization process [11]. Through the analysis of the above empirical results, the main conclusions of this paper are as follows.

The impact of environmental regulation on GTFP has regional heterogeneity, and its impact depends on the size of technology density. There are different optimal technology density intervals between the transfer out place and the receiving place. In terms of control variables, the increase of industrial scale and industrial proportion has a positive impact on GTFP. FDI has a positive impact on the industrial GTFP of the places where high energy consuming industries are transferred out, but has a negative impact on the industrial GTFP of the places where high energy consuming industries are undertaken.

In view of the above conclusions, this paper puts forward policy recommendations from the following aspects.

Less developed areas should increase R&D investment, increase technology density, and pay attention to scientific and technological innovation and the conversion rate of scientific research achievements. When formulating environmental protection policies, local governments should take into account the actual local conditions, not blindly follow the example of other regions, and should revise and adjust environmental protection policies in a timely manner. When formulating relevant laws and regulations, the state should strengthen the coordination and cooperation between neighboring regions and put an end to the "free riding" behavior of upstream provinces. In addition, the industrial undertaking areas should also pay attention to the quality of FDI when attracting foreign investment, and make use of FDI to generate positive technology spillovers, which must not cause irreversible damage to the environment for temporary economic interests.

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