Research on Threshold Effect of Environmental Regulation and Green Total Factor Productivity

Cao guangyuan, Dong zhiyuan, Zhang zenglian

Donlinks School of Economics and Management, University of Science and Technology Beijing, Beijing, China

Abstract. This paper selects the panel data of 30 provinces in China from 2005 to 2016, and uses the threshold effect model to analyze the correlation between environmental regulation and green total factor productivity (GTFP). The results show that: The impact of environmental regulation on GTFP is non-linear and has a double threshold effect. Therefore, the local governments of all provinces should continue to play a positive role in environmental regulation, reasonably adjust the level of environmental regulation according to local specific economic development and industrialization level, etc., and strive to promote the transformation of medium and high polluting enterprises to green environmental protection enterprises..

1 Introduction

Facing the deterioration of the ecological environment, state agencies and government departments have successively issued a series of guidelines and policies. The environmental pollution and ecological damage in China have been effectively controlled, and environmental regulation has played a positive role in improving ecological environment. However, the role of environmental regulation in economic growth and industrial productivity improvement has not yet been unified.

2 LITERATURE REVIEW

The existing literature on environmental regulation and GTFP is mainly concentrated in three aspects: the impact of environmental regulation; the calculation method of GTFP; and the role of environmental regulation in GTFP. The role of environmental regulation is mainly reflected in the two aspects of innovation in production technology and economic growth. Walley & Whitehead (1994) , Gray W B & Shadbegian R J (2003) believe that the implementation of environmental regulation policies puts higher demands on energy conservation and emission reduction of enterprises.

In the existing literature, there are numerous studies on the measurement method of GTFP. Yang Shidi, Han Xianfeng, and Song Wenfei (2017) incorporated environmental pollution and energy consumption into the accounting framework system of TFP, and measured the Chinese GTFP index by the data envelopment analysis (DEA) Malmquist yield index method.

Regarding the impact of environmental regulation on GTFP, scholars have not yet formed a consensus. Porter (1995), Zhang (2011) and other scholars believe that appropriate environmental regulations force companies

to adopt advanced technology and management, improve resource utilization, and thus increase TFP. Li Bin (2013) empirically analyzed the industrial industry data and pointed out that there were three threshold effects of environmental regulation on the impact of GTFP.

Through research on previous literatures, the existing literature on environmental regulation and GTFP mainly focuses on the role of environmental regulation, the measurement of GTFP, and the impact of environmental regulation on GTFP. Based on this, this paper introduces the threshold effect model into the research of the thesis, analyzes the threshold effects of environmental regulation and GTFP.

3 RESEARCH DESIGN

3.1 Hypothesis development

Some scholars have proposed that the relationship between environmental regulation and GTFP is complex and diverse. Domazlicky & Weber (2004) pointed out that there is uncertainty about the impact of environmental regulation on TFP. Li Ling and Tao Feng (2012) and Yin Baoqing (2012) have shown that the relationship between environmental regulation and enterprise technological innovation and technological progress rate is U-shaped. Li Bin (2013) used the panel threshold model to estimate the relationship between environmental regulation and GTFP. The study found that the effect of environmental regulation on GTFP does have a "threshold effect". Jing Weimin and Zhang Wei (2014) conducted research on environmental regulation and green progress of Chinese industry, and found that the impact of environmental regulation on China's industrial green progress is nonlinear. Wang and Shen (2016) pointed out that the relationship between

---

* Corresponding author: zhangzl@manage.ustb.edu.cn

environmental regulation and TFP is "U" type. It can be inferred that the impact of environmental regulation on GTFP is not a single linear relationship. Thus, put forward hypothesis: There is a threshold effect on the impact of environmental regulation on GTFP.

3.2 Definition of variables

Explained variable. GTFP (GTFP), based on the determined input-output data, this paper uses the SBM-Undesirable model to measure the GTFP (GTFP) of China's 30 inter-provincial economic units from 2005 to 2016, considering energy consumption and environmental pollution. The output indicators for this paper include expected and undesired outputs, as specified below: (1) Elemental input. Inputs include labor input, capital investment, and energy input. Labor input: Select the number of employees in the whole society as an indicator of labor input. Capital investment: Capital stock is used as the capital input index, but there is no existing data in the capital stock. This paper adopts the "permanent inventory method" adopted by most scholars, and estimates it based on 2005. For the selection of related variables and indicators, refer to Zhang Jun et al. (2004)[37]. Energy input: The total energy consumption of each province is used as an indicator of energy input. (2) Expected output. Lin Boqiang and Sun Chuanwang (2011)[38] believe that for China, the steady growth of GDP at this stage is crucial to achieving coordinated economic development. Therefore, this paper selects the actual GDP of each province calculated at the constant price of 2005 to express the expected output. (3) Unexpected output. Drawing on the practice of Xu Xiaohong and Wang Xia (2016) [35], this paper uses the entropy method to integrate industrial wastewater discharge, industrial exhaust emissions and industrial solid waste emissions into an environmental pollution comprehensive index to measure unexpected output.

Explanatory variables. Environmental Regulation (ER), which is measured by the amount of investment in industrial pollution control in various regions. We in order to ensure the rationality and reliability of the results, the investment amount of industrial pollution control in various regions is standardized.

Control variables. We in order to verify the existence of the "environmental Kuznets curve", it is expressed in terms of GDP per capita (GDP) and its squared term (GDP2). Shen Neng (2013)[39] pointed out in his research that enterprises in different industries may have different elastic coefficients and extreme values for the intensity of environmental regulation; at the same time, the differences in industrial structure between China's provinces will also have different effects on GTFP. Therefore, the industrial structure (IS) is taken into account and measured by the ratio of the added value of the secondary industry to the added value of the tertiary industry. The level of financial self-sufficiency (SF) reflects the ability and effectiveness of government administration. When the financial self-sufficiency rate is high, the government's income can well meet the

needs of general public service expenditure. On this basis, the government will pay more attention to environmental protection and governance, and environmental regulation will play a greater role. The relationship between TFP has increased. Express the financial self-sufficiency rate as the ratio of the general budgetary revenue of local finance to the general budgetary expenditure of local finance. At the same time, the level of industrialization and the level of urbanization in each province are also controlled. The level of industrialization (IND) is measured by the ratio of total output to GDP of industrial enterprises above designated size. The level of urbanization (URB) is expressed as the ratio of urban population to permanent population at the end of the year.

Table 1: Definition and description of variables

Type	Name	Symbol	Definition or source
Explained variable	GTFP	GTFP	Based on the SBM-Undesirable model
Explanatory variable	Environmental regulation	ER	Standardized investment in industrial pollution control in various regions after standardization
Control variable	Per capita GDP	GDP	Per capita GDP
	Squared per capita GDP	GDP2	Squared per capita GDP
	Financial self-sufficiency rate	SF	Local finance general budget revenue / local finance general budget expenditure
	Industrial structure	IS	Second industry added value / tertiary industry added value
	ndustrialization level	IND	Gross sales value/GDP of industrial enterprises above designated size
	Urbanization level	URB	Urban population / permanent population at the end of the year

3.3 Sample selection and source of data

This paper selects the panel data of China's 30 inter-provincial economic units from 2015 to 2016. GTFP is calculated based on the SBM-Undesirable model. The basic data of factor input, expected output and non-expected output are mainly derived from the China Statistical Yearbook, China Environmental Statistics Yearbook and China Energy Statistics Yearbook of various provinces and cities over the years; environmental regulation data is derived from the China Environmental Statistics Yearbook and the China Energy Statistics Yearbook; the per capita GDP comes from the WIND database; the data on fiscal self-sufficiency rate, industrial structure, industrialization level and urbanization level are mainly from the official website of the National Bureau of Statistics and the China Statistical Yearbook of various provinces and cities.

4 ANALYSIS OF EMPIRICAL RESULTS

4.1 Descriptive statistics

Table 2 shows descriptive statistics. The total value of GTFP is 1, the minimum value is 0.217, and the average value is 0.714, indicating that the difference in GTFP varies greatly among different provinces. The minimum environmental regulation is -1.53, the maximum is 6.442, and the average is 3.82e-10, indicating that the environmental regulations vary greatly among provinces.

Table 2: Descriptive statistics

Variables	Symbol	N	Mean	Std.	Min	Max
GTFP	GTFP	360	0. 714	0.220	0. 217	1
ER	ER	360	3.82e-10	1.001	-1.053	6.442
GDP	GDP	360	3.666	2.257	0. 537	11.813
GDP^2	GDP2	360	18.514	23.721	0.289	139.541
FSSR	SF	360	0.520	0.196	0. 148	0. 951
IS	IS	360	0. 975	0. 527	0. 497	4.165
IL	IND	360	1.278	0. 405	0.435	2.350
UL	URB	360	0.524	0. 140	0. 268	0. 896

4.2 Analysis of Threshold Effect of Environmental Regulation and GTFP

This paper uses the threshold panel data model proposed by Hansen (1999) to test the impact of different levels of environmental regulation on GTFP. The form of the single threshold model is:

$$gtfp = \alpha_0 + \alpha_1 er_{it} \cdot I(er_{it} \le q) + \alpha_2 er_{it} \cdot I(er_{it} > q) + \alpha_3 X_{it} + \varepsilon_{it}$$

The panel model of the double threshold effect is expanded as follows:

$$gtfp = \alpha_0 + \alpha_1 er_{it} \cdot I(er_{it} \le q_1) + \alpha_2 er_{it} \cdot I(q_1 < er_{it} \le q_2) + \alpha_3 er_{it} \cdot I(er_{it} > q_2) + \alpha_4 X_{it} + \varepsilon_{it}$$

Table 3 shows the results of different threshold effects when GTFP is the dependent variable and environmental regulation is used as both the independent variable and the threshold variable. The P value of the double threshold test was 0.000, which was significant at the 1% level; neither the single and the triple threshold passed the significance test. Therefore, this paper chooses the double threshold model for research. The double thresholds are -0.508 and -0.550, respectively, and the 95% confidence intervals are [-0.970, 2.485], [-0.718, -0.538].

Table 3: Threshold Existence Test

Number of threshold	F- value	p - value	Threshold (significant leve)		
			1%	5%	10%
Single	3.745	0.107	9.132	5.637	3.868
Double	9.184***	0.000	6.734	4.822	3.553
Triple	2.617	0.133	8.137	3.895	2.999

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively (the same below).

We take GTFP as the explanatory variable, environmental regulations as explanatory variables and threshold variables, per capita GDP, squared per capita GDP, fiscal self-sufficiency rate, industrial structure, industrialization level and urbanization level as control variables, constructing a double threshold panel model for empirical regression analysis. Table 4 shows the regression results. The model (1) is the conventional fixed effect model; the model (2) is the fixed effect model considering the heteroscedasticity.

In model (1), when the intensity of environmental regulation is less than the threshold value of -0.550, the coefficient between environmental regulation and GTFP is 0.163, and is significant at the level of 1%, indicating that when environmental regulation is less than a certain level, environmental regulation has a positive effect on the improvement of GTFP; When the intensity of environmental regulation is greater than the threshold value of -0.550 and less than the threshold value of -0.508, the coefficient between environmental regulation and GTFP is -0.145, and is significant at the level of 5%, indicating that when the intensity of environmental regulation is in this interval, environmental regulation is negatively correlated with GTFP. When the intensity of environmental regulation is greater than the threshold value of -0.508, the coefficient between environmental regulation and GTFP is 0.174, and is significant at the level of 1%, indicating that when the intensity of environmental regulation is greater than -0.508, environmental regulation is positively correlated with GTFP, that is, with the increase of environmental regulation intensity, GTFP is gradually increased. The regression results of model (2) considering heteroscedasticity are consistent with model (1). It can be found that there is a nonlinear relationship between environmental regulation and GTFP, that is, the impact of environmental regulation on GTFP has a threshold effect, and hypothesis 1 is proved.

Table 4: Regression result

Variables	（1）fe	（2）fe_robust
er	-0.145** （-2.31）	-0.145* （-1.81）
er_1	0.163*** （2.85）	0.163** （2.31）
er_3	0.174*** （2.74）	0.174** （2.10）
gdp	0.095*** （3.43）	0.095** （2.37）
gdp2	-0.006*** （-3.25）	-0.006** （-2.45）
sf	0.064 （0.33）	0.064 （0.25）
Is	0.009 （0.18）	0.009 （0.13）
ind	-0.007 （-0.14）	-0.007 （-0.09）
urb	0.550 （1.27）	0.550 （0.70）
_cons	0.151	0.151

	（0.71）	（0.46）
Obs	360	360
F	27.01	15.83

In order to clarify the distribution of environmental regulations in various provinces in recent years, the environmental regulations of the provinces are classified and counted. The results are shown in Table 5. As time goes by, environmental regulation shows an overall upward trend: environmental regulations were concentrated in the interval between the two thresholds from 2006 to 2012; in 2013-2016, they were concentrated in the interval above -0.508. The two parts of environmental regulation have proved the levels of GTFP.

Table 5: Interval of Environmental Regulations

year	below -0.550		between -0.550 and -0.508		higher than -0.508	
	Province	province %	Province	province %	Province	province %
2005	13	41.94	1	3.23	17	54.83
2006	13	41.94	1	3.23	17	54.83
2007	10	32.26	2	6.45	19	61.29
2008	9	29.03	3	9.68	19	61.29
2009	11	35.48	1	3.23	19	61.29
2010	14	45.16	1	3.23	16	51.61
2011	12	38.71	3	9.68	16	51.61
2012	10	32.26	0	0	21	67.74
2013	6	19.35	0	0	25	80.65
2014	4	12.90	0	0	27	87.10
2015	4	12.90	2	6.45	25	80.65
2016	5	16.13	3	9.68	23	74.19
Sum	111		17		244	

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the threshold effect model and the spatial econometric model, this paper studies the relationship between environmental regulation and GTFP based on the panel data of 30 provinces in 2005-2016. The study found that the impact of environmental regulation on GTFP is non-linear and has a double threshold effect. When the intensity of environmental regulation is less than the threshold value of -0.550, environmental regulation is positively correlated with GTFP, that is, environmental regulation has a positive effect on the improvement of GTFP; when the intensity of environmental regulation is greater than the threshold value of -0.550 and less than the threshold value of -0.508, environmental regulation is negatively correlated with GTFP. The greater the intensity of environmental regulation, the lower the level of GTFP. When the intensity of environmental regulation is greater than the threshold value of -0.508, environmental regulation is positively correlated with GTFP, that is, with the increase of environmental regulation intensity, GTFP is

gradually increased. Through the statistics of the environmental regulations of various provinces in China, it is found that the environmental regulation levels of various provinces in China are basically distributed on both sides of the threshold. In other words, China's environmental regulation is positively correlated with GTFP. With the moderate increase in the intensity of environmental regulation, the level of GTFP in the provinces continues to increase. Therefore, provinces with an environmental regulation intensity lower than -0.550 should maintain environmental regulations and ensure that the maximum effect of environmental regulation on GTFP is exerted within this interval. Provinces with an environmental regulation between -0.550 and -0.508 should reduce the intensity of environmental regulation and reduce the investment in environmental protection costs according to their actual conditions, so as to ensure the rational use of corporate funds. Provinces with an environmental regulation intensity greater than -0.508 should continue to strengthen the intensity of environmental regulation, and strive to promote the transformation of medium and high-pollution enterprises to green environmental protection enterprises and realize the transformation and development of these enterprises.

References

1. Gray W B, Shadbegian R J. Plant vintage, technology, and environmental regulation[J]. Journal of Environmental Economics & Management, 2003, 46(3):384-402.

2. Horbach J. Determinants of environmental innovation—New evidence from German panel data sources[J]. Research Policy, 2008, 37(1):163-173.

3. Zhang Cheng, Lu Wei, Guo Lu, etc. Environmental regulation intensity and production technology progress [J]. Economic Research Journal,2011(2) : 113-124.

4. Hu An'gang, Zheng Jinghai, Gao Yuning, etc. Provincial technical efficiency ranking considering environmental factors (1999-2005) [J]. China Economic quarterty, 2008(3):933-960.

5. Hu Xiaozhen, Yang Long. Analysis on the Difference and Convergence of GTFP Growth in China[J].J ournal of Finance and Economics,2011, 37(4):123-134.

6. Wang Feng, Jie Jin. Research on the Growth Rate of GTFP in China by Province [J]. Chinese Journal of Population Science，2015(02):53-62.

7. Yang Shidi, Han Xianfeng, Song Wenfei. Does foreign direct investment affect China's GTFP[J]. Journal of Shanxi University of Finance and Economics, 2017, 39(04) :14-26.

8. Song Malin, Wang Shuhong. Environmental regulation, technological progress and economic growth [J]. Economic Research Journal,2013,48(03):122-134.

9. Li Ling, Cao Feng. The Choice of the Optimum Environmental Regulation Intensity of Manufacturing Industry in China [J]. China Industrial Economics, 2012(5):70-82.

10. Yin Baoqing. Carbon emissions from imported intermediates, environmental regulation and technological innovation of local enterprises [J]. Academic Forum, 2012, 35(3):125-129.