

Research on the Impact of Environmental Regulation on Green Total Factor Productivity from the Perspective of Human Capital

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Abstract: Strengthening environmental regulation is crucial for China to achieve the carbon peaking and carbon neutrality goals, but excessive environmental regulation will increase the production costs of enterprises, thereby reducing output and productivity. Using the panel data of 30 provinces in China (excluding Tibet) from 2007 to 2016, we construct an empirical model between environmental regulation and green total factor productivity, and explores the impact of environmental regulation from the perspective of human capital. The results show that the relationship between environmental regulation and green total factor productivity presents a U-curve relationship, and when environmental regulation is high, the increase of human capital will weaken the promotion effect of environmental regulation on green total factor productivity. In addition, most of the observed samples are located on the left side of the U-shaped curve, indicating that China's current environmental regulation-related policies are unreasonable, and environmental regulation needs to be further strengthened.

Keywords: Environmental regulation; Green total factor productivity; U- curve; Human capital.

1. Literature Review and Theoretical Hypotheses

After the reform and opening up, Chinese total economic output has grown rapidly, but the extensive industrial growth model of high investment, high energy consumption and high emissions have also caused China to accumulate many disadvantages in the environmental field, and the green total factor productivity is low. The study found that between 2001 and 2010, the green total factor productivity of Chinese industrial sub-sectors did not grow, but instead experienced a certain regression (Li, Peng and Ouyang, 2013). The severe environmental situation is increasingly becoming an important factor restricting the sustainable development of Chinese economy. In order to improve the ecological environment and comprehensively increase green total factor productivity, the Chinese government has issued a series of strict environmental regulation policies.

As for the impact and mechanism of environmental regulation on green total factor productivity, the academia still has different views. The traditional view holds that the enhancement of environmental regulation increases the cost of enterprises in the short term, increases the environmental protection burden of enterprises, and inhibits the productivity and profitability of enterprises, which is not conducive to economic growth (Gray and Shadbegian, 1993). Some scholars holds the view that the loss of factor productivity can improve the level of such technologies by forcing enterprises to carry out environmentally friendly technological innovations, but it cannot offset the losses caused by the reduction of total factor productivity to enterprises, and the environment and economic development cannot be balanced (Ricci, 2007; Popp and Newell, 2012); environmental regulation reduces total factor productivity in pollution-intensive industries (Greenstone, 2002). However, some scholars pointed out that in the long run, an appropriate level of environmental regulation will stimulate enterprises to innovate in environmental protection technology, help

enterprises to reduce pollution and adopt newer and more efficient production technologies and equipment to increase productivity and offset the negative impact on factor productivity (Porter, 1991; Porter and Van, 1995). With the further research, scholars have begun to perceive that the relationship between environmental regulation and green total factor productivity may not be a simple promotion or inhibition relationship. Some scholars have found that the relationship between the intensity of environmental regulation and the green total factor productivity of the manufacturing industry conforms to a U-shaped relationship (Li and Tao, 2012; Yin, 2012). The intensity of environmental regulation has an impact on green total factor productivity that first weakens and then increases. Environmental regulation will have a negative impact on the technological progress of enterprises in the short term, but in the long run, it will stimulate enterprises to carry out technological innovation and improve green total factor productivity, and there are certain differences in this impact between clean sectors and pollution-intensive sectors. Based on the above research, we propose the following hypothesis:

Hypothesis 1: The impact of environmental regulation on green total factor productivity presents a U-shaped characteristic.

Most of the above studies are based on the analysis of the impact of environmental regulation on the technological level and R&D investment of enterprises, and then on the total factor productivity of enterprises, but there are few studies on the factor of human capital. Some scholars studied the impact of environmental regulation on economic growth from the perspective of human capital, and found that when environmental regulation reaches a high level, environmental regulation and environmental regulation through human capital channels will inhibit economic growth (Wang, 2016). Some others found that, through their research on the policies of the two control, the high level of environmental regulation will force enterprises to increase the demand for R&D personnel and improve the level of human capital, which is

limited in the path of transforming human capital into output, making GTFP not increase but decrease (Li, Liu and Wang, 2019). Referring to relative study, we use human capital as a channel to examine the moderating effect of human capital in the relationship between environmental regulation and green total factor productivity. The following hypothesis is proposed:

Hypothesis 2: When human capital is large, stronger environmental regulation will have an inhibitory effect on green total factor productivity.

2. Variables and Empirical Model

2.1. Selection of variables

In this paper, we mainly study the correlation between environmental regulation and green total factor productivity (GTFP) and the moderating effect of human capital on it. We select panel data from 2007 to 2016 of 30 provinces and cities in China (excluding Tibet) as the research sample, takes the comprehensive index of environmental regulation as the core explanatory variable, and green total factor productivity as the explained variable, and constructs an econometric model for empirical analysis.

Explained variable: Green Total Factor Productivity (GTFP). We select the green total factor productivity of each province obtained by the standard deficient SBM-GML

model in the database as the explained variable.

The core explanatory variable: Environmental Regulation Index (ERI). At present, the measurement for environmental regulation are not unified, and the data in some indicators are relatively incomplete. Some scholars start from the perspective of pollutant emission levels (Huang et al., 2015). Therefore, we use the entropy method to deal with the industrial wastewater discharge, industrial sulfur dioxide discharge and industrial soot discharge in each province respectively, and add up and average to obtain the final environmental regulation index.

Moderating variable: human capital (HUMAN). Referring to the conclusions of related studies (Wang, 2016), environmental regulation can have an impact on economic growth through the channel of human capital. Therefore, we select the human capital index in the CSMAR database as the moderating variable of the research.

Control variables: Referring to the practice of related research (Tong, Liu and Xue, 2016), we select urbanization rate (URBAN), fiscal expenditure (GOV), foreign trade dependence (TRAD), ownership structure (NAT) and technology investment (TECH) as the control variables of the research.

Definitions of all variables used in this study are given in Table 1 and data source includes CSMAR, statistical yearbooks and so on.

Table 1. Definitions of variables

variable type	variable name	variable symbol	variable description
Explained variable	Green total factor productivity	GTFP	SBM-GML model estimated value
Explanatory variable	Environmental regulation index	ERI	weighted average pollutant emission level obtained by entropy method
	Urbanization rate	URBAN	urban population/year-end resident population
	Fiscal expenditure	GOV	local general budget expenditure/local GDP
Control variables	Foreign trade dependence	TRAD	total import and export/local GDP
	Ownership structure	NAT	sales output value of SOE/sales output value of enterprises above designated size
	Technology investment	TECH	technology expenditure/general public expenditure
Moderating variable	Human capital	HUMAN	logarithm of the number of students in colleges and universities per 10,000 people in the city

Notes: This table presents the symbols and definitions of the variables used in this paper.

2.2. Establishment of the empirical model

We focus on the nonlinear relationship between environmental regulation and green total factor productivity, and conducts a test on the moderating effect of human capital, thus constructing a multiple linear regression model.

First, referring to the research on the U-shaped relationship between environmental regulation and green total factor productivity (Li and Tao, 2012), we establish the following multiple linear regression model by adding the quadratic term of the core explanatory variable environmental regulation index,

$$GTFP_{it} = \theta_0 + \theta_1 ERI_{it} + \theta_2 ERI_{it}^2 + \eta X_{it} + V_i + \epsilon_{it} \quad (1)$$

where i denotes the 30 provinces and cities in the data, t denotes the year, ERI_{it} is the environmental regulation index, and X_{it} denotes the control variables, including the urbanization rate ($URBAN_{it}$), fiscal expenditure (GOV_{it}), the ownership structure (NAT_{it}), and foreign trade dependence ($TRAD_{it}$) and technology investment ($TECH_{it}$), V_i is the individual effect, and ϵ_{it} is the random disturbance term.

Then, referring to the practice of using human capital as a

channel in related papers (Wang, 2016), we added the multiplication term of the environmental regulation index and human capital into the basic regression. The specific model is as follows,

$$TFP_{it} = \theta_0 + \theta_1 ERI_{it} + \theta_2 ERI_{it}^2 + \alpha HUMAN_{it} + \beta ERI_{it} \cdot HUMAN_{it} + \eta X_{it} + V_i + \epsilon_{it} \quad (2)$$

where $HUMAN_{it}$ denotes human capital, and the rest are defined as above.

3. Empirical Analysis and Sensitivity Analysis

3.1. Summary statistics

It can be seen from the summary statistics of the variables that the core explanatory variable Environmental Regulation Index (ERI) has a large range, the maximum value is 1.968, the minimum value is 0, the mean value is 0.521, and the standard deviation is 0.518. The range of the explained variable green total factor productivity is above 4, indicating that there is a certain gap in the development of green

industries in various provinces. Finally, the unit root test is carried out, and the results are all less than 0.05, indicating that the null hypothesis is rejected at the 5% significance level, that is, there is no unit root, and the stationarity test is passed. We report summary statistics of the variables in Table 2.

Table 2. Summary statistics

	count	mean	sd	min	max
GTFP	300	1.405	0.747	0.419	4.560
ERI	300	0.521	0.518	0.000	1.968
URBAN	300	0.538	0.136	0.307	0.893
TRAD	300	0.318	0.360	0.043	1.530
GOV	300	0.241	0.110	0.099	0.723
NAT	300	0.369	0.180	0.103	0.800
TECH	300	0.019	0.013	0.007	0.062
HUMAN	300	5.135	0.321	4.245	5.813

Notes: This table presents the summary statistics of the variables used in basic regression. See Table 1 for detailed variable definitions.

Table 3. Basic regression results

	(1) POLS	(2) FE	(3) RE	(4) FE
ERI	-1.659*** (-6.61)	-0.440*** (-2.66)	-0.405** (-2.49)	1.750** (2.17)
ERI 2	1.256*** (9.16)	0.166** (2.01)	0.182** (2.21)	0.252*** (2.88)
URBAN	2.610*** (3.84)	4.214*** (7.48)	4.094*** (8.06)	4.243*** (7.63)
GOV	-1.350*** (-2.59)	-0.190 (-0.51)	-0.518 (-1.51)	-0.271 (-0.74)
TRAD	-0.433* (-1.94)	-0.730*** (-6.33)	-0.762*** (-7.13)	-0.804*** (-6.87)
NAT	-0.318 (-1.39)	-0.238 (-0.88)	-0.438* (-1.80)	-0.177 (-0.66)
TECH	0.945 (0.16)	2.660 (0.88)	2.508 (0.83)	2.386 (0.80)
HUMAN	-0.200 (-1.09)	-0.536*** (-3.59)	-0.485*** (-3.37)	-0.339** (-2.07)
ERI HUMAN				-0.474*** (-2.77)
cons	1.780** (2.08)	2.345*** (3.53)	2.286*** (3.47)	1.419* (1.93)
Prov FE	NO	YES	YES	YES
Year FE	NO	YES	YES	YES
N	300	300	300	300
R2	0.455	0.563	0.560	0.576

Notes: This table presents the basic regression results. The dependent variable is green total factor productivity, and the independent variable is the environmental regulation index. We control for the prespecify characteristics: URBAN, GOV, TRAD, NAT, TECH. And HUMAN is this paper's moderating variable. In Columns (1), (2) and (3), this paper separately uses POLS, FE and RE model to examine U-curve relationship between GTFP and ERI. In columns (4), this paper adds the intersection to examine moderating effect. See Table 1 for detailed variable definitions. T-statistics of the coefficient estimates are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

With the strengthening of environmental regulation, green total factor productivity declines, and environmental regulation has a negative effect on it, but after the inflection point is exceeded, environmental regulation has a positive impact on green total factor productivity.

After a simple estimation, the size of the inflection point obtained in this paper is about 1.11, indicating that when the environmental regulation index is less than 1.11, in order to meet the regulatory standards, enterprises increase production costs and reduce production scale, resulting in a decline in green total factor productivity. When the intensity of environmental regulation is greater than 1.11, with the increase of the intensity of environmental regulation, the green total factor productivity increases significantly, which may be due to the “reverse forcing effect” of environmental regulation on production enterprises (Zhong, Li and Du, 2015), which makes enterprises improve production

3.2. Basic regression results

According to Eq. (1), we regress the corresponding variables, and Table 3 reports the basic regression results. Among them, column (1) gives the regression results obtained by hybrid OLS model, column (2) gives the regression results obtained by fixed effects model, and column (3) gives the regression results obtained by random effects model. The Hausman test is performed on the regression results of column (2) and column (3), and the obtained p value is 0.0049, which significantly indicates there is a significant difference in coefficient estimation between fixed effects model and random effects model, so the fixed effect model is better.

Further observation of the estimated coefficients shows that the coefficient of the primary term of environmental regulation is negative, about -0.4, while the coefficient of the quadratic term of environmental regulation is positive, about 0.18, and both coefficients are significant under the 5% level. Environmental regulation has a significant impact on green total factor productivity, and the U-shaped relationship between them is verified. Hypothesis 1 holds.

technology, increase innovation and research and development, thereby improving green total factor productivity.

At the same time, most of the sample data selected in this paper are located on the left side of the U-shaped curve, that is, increasing environmental regulation will lead to a decline in green total factor productivity, indicating that China's current environmental regulation policies are partly unreasonable. In conclusion, it is necessary to further strengthen environmental regulation, so that the level of each province and city can reach the right side of the U-shaped curve, give full play to the “reverse forcing effect” of environmental regulation on enterprises, and improve green total factor productivity, realizing the simultaneous development of economy and environment.

In addition, the two control variables of urbanization rate (URBAN) and foreign trade dependence (TRAD) have a

significant impact on green total factor productivity at the 1% significance level. Among them, the coefficient of urbanization rate is positive, which is about 4.09, that is, when other factors are kept constant, the green total factor productivity will increase by about 0.04 for every 0.01 increase in the urbanization rate. At the same time, the coefficient of foreign trade dependence is negative, about -0.762, that is, when other factors are kept unchanged, for every 0.01 increase in foreign trade dependence, green total factor productivity will decrease by about 0.0076, so its impact is limited.

We also consider the impact of human capital on the relationship between environmental regulation and green total factor productivity, so on the basis of the fixed effects model, the multiplication term of human capital and environmental regulation (ERI HUMAN) is added, and column (4) reports the corresponding regression results. It can be found that the coefficient of the multiplication term of human capital and environmental regulation is negative, about -0.47, and has a significant impact on green total factor productivity at the 1% significance level, indicating that human capital will change the impact mechanism of environmental regulation on green total factor productivity. Hypothesis 2 holds.

When the environmental regulation is high, the capacity of human capital to be converted into output is limited, and the

increase of human capital will weaken the promotion effect of environmental regulation on green total factor productivity, resulting in a decline in GTFP.

3.3. Endogeneity analysis

The main sources of endogeneity in the research are three parts. First, environmental regulation policies will be partially revised with the development of various regions. Second, we use provincial panel data in the research, but environmental regulation data in some regions are missing, which will lead to omission of relevant variables. Third, when formulating policies, the government will give priority to strengthening the intensity of environmental regulation in areas with more developed industries and serious pollution, resulting in a two-way causal relationship between environmental regulation and green total factor productivity, resulting in serious endogenous problems.

In order to solve the endogeneity problem, we first use the lag term of environmental regulation as an instrumental variable, and at the same time refer to the relevant research of domestic and foreign scholars (Laura and Sandra, 2014), use the air circulation coefficient (AFC) as an instrumental variable, and take the two-stage least squares method to carry out the endogeneity analysis. Table 4 reports the result of endogeneity analysis.

Table 4. Endogeneity analysis results

	Iv (1)	iv (2)	ERI (-1)	ERI (-1), ERI (-2)	Iv (3) AFC
ERI			-1.793*** (-6.91)	-1.893*** (-6.93)	-1.659*** (-6.71)
ERI 2			1.321*** (9.49)	1.362*** (9.50)	1.256*** (3.33)
URBAN			2.658*** (3.74)	2.727*** (3.60)	2.610*** (3.90)
GOV			-1.549*** (-2.71)	-1.770*** (-2.80)	1.350*** (-2.63)
TRAD			-0.343 (-1.38)	-0.239 (-0.84)	-0.433** (-1.97)
NAT			-0.252 (-1.05)	-0.200 (-0.77)	-0.318 (-1.41)
TECH			-1.292 (-0.22)	-3.986 (-0.66)	0.945 (0.16)
HUMAN			-0.254 (-1.23)	-0.329 (-1.41)	-0.200 (-1.10)
cons			2.115** (2.18)	2.569** (2.30)	1.780** (2.12)
					300
N	Sargan Sargenp		270	240	42.964
					0.0000***

Notes: This table presents the endogeneity analysis results. Column (1) gives the regression results obtained by taking the first-order lag of the primary term of environmental regulation index as an instrumental variable, column (2) presents the regression results obtained by taking the first-order and second-order lags of environmental regulation as instrumental variables, and column (3) gives the regression results obtained by taking the primary term of the air circulation coefficient (AFC) as an instrumental variable. T-statistics of the coefficient estimates are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Among them, column (1) presents the regression results obtained by taking the first-order lag of the primary term of environmental regulation index as an instrumental variable, column (2) presents the regression results obtained by taking the first-order and second-order lags of environmental

regulation as instrumental variables, column (3) presents the regression results obtained by taking the primary term of the air circulation coefficient (AFC) as an instrumental variable, and column (4) presents the regression results obtained by using the air circulation coefficient and its quadratic terms as

the instrumental variables of the primary and quadratic terms of environmental regulation index.

The results show that the model (3) has a large number of instrumental variables, which may have the problem of over-identification. Therefore, the Sargant test is carried out, and the obtained p value is close to 0, and the null hypothesis is significantly rejected at the 1% level, that is, there is no problem of over-identification. At the same time, the estimated coefficients of environmental regulation index (ERI) and the quadratic term of environmental regulation index (ERI 2) are both significant at the 1% level, indicating that the effect of environmental regulation on green total factor productivity presents a U-shaped curve, which is consistent

with the previous analysis, so the estimated results in this paper are robust.

3.4. Robustness check

In order to verify the robustness of the above results, we use the green total factor productivity (GTFP2) obtained by super-efficient SBM-GML model as the explained variable, and performs the same estimation on Eq. (2.1). Table 5 reports the results of the robustness test. Comparing the obtained regression results with the benchmark regression results obtained above, it can be found that the two results are similar, so the conclusion of this paper is robust.

Table 5. Robustness check results

	(1) POLS	(2) FE	(3) RE	(4) FE
ERI	-1.661*** (-6.60)	-0.436*** (-2.60)	-0.400** (-2.44)	1.782** (2.18)
ERI 2	1.259*** (9.15)	0.165** (1.97)	0.180** (2.17)	0.252*** (2.85)
URBAN	2.614*** (3.84)	4.150*** (7.28)	4.049*** (7.90)	4.179*** (7.42)
GOV	-1.347** (-2.58)	-0.195 (-0.52)	-0.524 (-1.52)	-0.277 (-0.75)
TRAD	-0.433* (-1.94)	-0.742*** (-6.36)	-0.771*** (-7.14)	-0.817*** (-6.90)
NAT	-0.319 (-1.39)	-0.252 (-0.92)	-0.448* (-1.82)	-0.190 (-0.70)
TECH	0.910 (0.15)	2.560 (0.84)	2.451 (0.80)	2.283 (0.75)
HUMAN	-0.196 (-1.06)	-0.510*** (-3.38)	-0.462*** (-3.18)	-0.311** (-1.88)
ERI HUMAN				-0.480*** (-2.77)
cons	1.753** (2.05)	2.259*** (3.36)	2.202*** (3.31)	1.322* (1.78)
Prov FE	NO	YES	YES	YES
Year FE	NO	YES	YES	YES
N	300	300	300	300
R2	0.455	0.559	0.555	0.571

Notes: This table presents the robustness check results. We replace the measurement of green total factor productivity to carry out the robustness check. T-statistics of the coefficient estimates are reported in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

4. Conclusion

In this paper, we empirically test the impact of current environmental regulation on green total factor productivity in China, and explores the moderating effect from the perspective of human capital. The results show that: (1) The relationship between environmental regulation and green total factor productivity presents a U-curve relationship, and the inflection point is about 1.11. When environmental regulation exceeds 1.11, the reinforcement of environmental regulation has a positive impact and will further improve green total factor productivity, which may be due to the “reverse forcing effect” (Zhong, Li and Du, 2015). (2) At present, China is still on the left side of the U-shaped curve, that is to say, increasing environmental regulations will lead to a decrease in green total factor productivity. The possible reason is that there are still many enterprises that do not meet environmental standards. When environmental regulation reinforces, the production costs of enterprises will increase, thus reducing output and green total factor productivity. (3) Under the current intensity of environmental regulation, the ability of human capital to be converted into output is limited. When human capital increases, green total factor productivity will not increase accordingly. (4) Human capital will change the impact mechanism of environmental regulation on green total factor productivity: when environmental regulation is

high, the increase of human capital will weaken the promotion of environmental regulation on green total factor productivity. The empirical results of this paper have certain policy implications. First of all, China should continue to increase investment in environmental governance, rationally design specific forms of environmental regulation, and enhance the intensity of environmental regulation in most areas, so that China can enter the right side of the U-shaped curve as soon as possible, and achieve a “win-win” between environmental protection and economic growth. In addition, structural adjustment is needed to correct the distortion of human capital. At present, the role of human capital in improving green total factor productivity is not positive, which is opposite to the role of human capital in the traditional economic growth model, indicating that the role of human capital in promoting green development in China is not obvious. Correcting the distortion of human capital is of great significance to the coordinated development of industrial greening and industrial digitalization in China.

In addition, the research still has some limitations. First, due to incomplete data, we only calculate the environmental regulation index from the perspective of pollutant discharge, which can only reflect one aspect of environmental regulation, so it is a better choice to build a comprehensive environmental regulation index. Second, the endogeneity problem in this study is relatively serious. Although the lag term and air

circulation coefficient are selected as instrumental variables for testing, more methods should be found to improve the empirical model.

References

- [1] Gray, W B., and R J. Shadbegian. 1993. "Environmental regulation and manufacturing productivity at the plant level." Social science electronic publishing.
- [2] Greenstone, M. 2002. "The Impacts of Environmental Regulation on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." *Journal of Political Economy*, 110(6): 1175–1219.
- [3] Huang, Zhiji, Can He, Fan Yang, and Yi Zhou. 2015. "Environmental regulation geographic location and growth of firms' productivity in China." *Acta Geographica Sinica*, 70(10): 1581–1591.
- [4] Laura, Hering, and Poncet Sandra. 2014. "Environmental policy and ex-ports: Evidence from Chinese cities." *Journal of Environmental Economics and Management*, 68(2): 296–318.
- [5] Li, Bin, Xing Peng, and Mingke Ouyang. 2013. "Environmental Regulation, Green Total Factor Productivity and the Transformation of China's Industrial Development Mode--Analysis Based on Data of China's 36 Industries." *China Industrial Economics*, 56–68.
- [6] Li, Ling, and Feng Tao. 2012. "Selection of Optimal Environmental Regulation Intensity for Chinese Manufacturing Industry--Based on the Green TFP Perspective." *China Industrial Economics*, 70–82.
- [7] Li, Weibing, Fangwen Liu, and Bin Wang. 2019. "Can Environmental Regulation Promote GTFP? -Evidence from the Two Control Zones Policy." *Journal of Huazhong University of Science and Technology (Social Science Edition)*, 33(1): 72–82.
- [8] Popp, D., and R. Newell. 2012. "Where Does Energy R&D Come From? Examining Crowding Out from Energy R&D." *Energy Economics*, 51(1): 46–71.
- [9] Porter, M. E. 1991. "American's Green Strategy." *Scientific American*, 264(4): 193–246.
- [10] Porter, M. E., and L. C. Van. 1995. "Toward a New Conception of the Environment-competitiveness Relationship." *Journal of Economic Perspectives*, 9(4): 97–118.
- [11] Ricci, F. 2007. "Channels of Transmission of Environmental Policy to Economic Growth: A survey of the Theory." *Ecological Economics*, 60(4): 688–699.
- [12] Tong, Jian, Wei Liu, and Jing Xue. 2016. "Environmental Regulation, Factor Input Structure and Industrial Transformation." *Economic Research Journal*, 51(07): 43–57.
- [13] Wang, Hongqing. 2016. "Study on Threshold Effects of Environmental Regulation on Economic Growth from the Perspective of Human Capital." *China Soft Science*, 52–61.
- [14] Yin, Baoqing. 2012. "Environmental Regulation and China's Green Total Factor Productivities: Based on the Perspective of Vertical Specialization." *China Population, Resources and Environment*, 22(12): 60–66.
- [15] Zhong, Maochu, Mengjie Li, and Weijian Du. 2015. "Can Environmental Regulation Force Industrial Structure Adjustment: An Empirical Analysis Based on Provincial Panel Data." *China Population, Resources and Environment*, 25(08): 107–115.