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Study on the Evaluation of China's Environmental Regulation Effect: A Spatial Perspective Based on Industrial Green Development**

Abstract

On the basis of a comprehensive understanding of green growth and efficiency, this paper constructs the metrics of industrial green development in China and adopts the spatial Durbin model to analyze the panel data of provincial industrial sector during 1998 and 2012, aiming to test the effect of China's environmental regulation empirically by taking the spatial influence of regional environmental regulation into account. It is found that: (1) no matter which spatial weight matrix, geographic adjacency, economic development level or geographical economic adjacency, is used, China's environmental regulation is significantly effective to industrial green development as a whole. However, regional environmental regulation does not effectively promote the industrial green development of the region, but has a significant positive spillover effects on other regions. So, the effectiveness of China's overall environmental regulation is mainly decided by the spatial spillover effects from other regions. (2) Industrial green development in the region may be transferred through pollution-intensive industries, thus has an adverse spatial impact on the industrial sectors of other areas. (3) Firm size, industrial capital intensity and industrial innovation help promote regional industrial green development, while ownership structure and external trade play an unfavorable role. What's more, the promoting effect of foreign direct investment is not significant.

Keywords: *Environmental Regulation, Green Total Factor Productivity, Industrial Green Development, Spatial Durbin Mode*

1. Introduction

As a main way to solve environmental problems, government environmental regulation basically is to force each economic agent to reduce pollutant emissions and comply with environmental laws and regulations so as to create a good ecological environment, by relying on government's authority and tangible institutional arrangements. The ultimate goal of environmental regulation is to change the traditional extensive economic growth mode and achieve green and sustainable economic growth. Under the background that global economy development is generally unsustainable, when pursuing economic development, each country is paying more and more attention to the "green development" mode.[1] On the one hand, green development requires the development of economy; on

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1 T. G. Ehresman, C. Okereke, "Environmental Justice and Conceptions of the Green Economy", *International Environmental Agreements: Politics, Law and Economics*, vol.15, no.1, 2015, pp. 13-27.

the other hand, it emphasizes the principle of sustainability and environmental protection. Green development is essentially a production mode which tries to improve output efficiency while reducing the input of non-renewable factors and pollutant emissions at the same time.

At present, many scholars have carried out newest researches on the effects of Chinese environmental regulation, which mainly focus on the influence of environmental regulation on economic growth, technological innovation and total factor productivity[2].

As long as the environmental regulation is within a reasonable range, it will promote the improvement of total factor productivity. However, these researches from the perspective of economic growth, technological innovation or total factor productivity can not fully evaluate the actual role of environmental regulation in economic green development, because economic growth, technological innovation and total factor productivity are only the necessary condition but not sufficient condition when environmental regulation plays a role. When environmental regulation promotes the growth of economic aggregate, if this growth still depends on traditional way of high input, high consumption and high emissions, even if the economy develops quickly, we cannot say that the environmental regulation has a positive effect on economy.

2. Evaluation Theories and Mechanism Analysis of Environmental Regulation Effect

It is necessary to comprehensively consider the various attributes of environmental regulation when evaluating and studying China's environmental regulation effects. This paper will be carried out from the three effects of environmental regulation when proposing theoretical basis to evaluate its effectiveness. (1) Green effect of environmental regulation.[3] (2) Technology innovation effect of environmental regulation.[4] (3) Growth effects of environmental regulation.[5]

In conclusion, effective and well implemented environmental regulations should have the following features, promoting growth, increasing efficiency and environmental protection. This paper believes that when evaluating the effect of China's environmental regulation it should examine the impact on industrial green development. If environmental regulation does not lead industries into a path of green development, the government

2 Jiang Fuxin, Wang Zhujun, Bai Junhong, "Dual Effects of Environmental Regulation on on Technological Innovation — Empirical Study based on Dynamic Panel Data of Jiangsu Manufacturing Industries(in Chinese)", *Journal of China Industrial Economics*, no.7, 2013, pp. 44-55; Zhao Xiaowei, "Competition Strategies of Local Government Environmental Regulation and Regional Growth Effect — Evidence from Above Prefecture-Level Cities (in Chinese)", *Journal of Finance & Trade Economics*, no.10, 2014, pp. 105-113, Wang Jie, Liu Bin, "Environmental Regulation and Enterprises Total Factor Productivity — Based on the Data of China's Industrial Enterprises (in Chinese)", *Journal of China Industrial Economics*, 2014, no.3, pp. 44-56.

3 M. Bhattarai, M. Hammig, "Institutions and the Environmental Kuznets Curve for Deforestation: A Cross-country Analysis for Latin America, Africa and Asia", *World Development*, vol.29, no.6, 2001, pp. 995-1010; A. M. Leiter, A. Parolini, H. Winner, "Environmental Regulation and Investment: Evidence from European Industry Data", *Ecological Economics*, vol.70, no.4, 2011, pp. 759-770.

4 M. E. Porter, C. Van der Linde, "Toward A New Conception of the Environment-Competitiveness Relationship", *The Journal of Economic Perspectives*, vol.9, no.4, 1995, pp. 97-118; P. Lanoie, M. Patry, R. Lajeunesse, "Environmental Regulation and Productivity: Testing the Porter Hypothesis", *Journal of Productivity Analysis*, vol.30, no.2, 2008, pp.1 21-128.

5 W. Thomas, "Do Environmental Regulations Impede Economic Growth? A Case Study of the Metal Finishing Industry in the South Coast Basin of Southern California", *Economic Development Quarterly*, vol.23, no.4, 2009, pp. 329-341.

cannot be regarded to have implemented effective environmental control measures.

The industrial green development of one region has some spatial influence on the surrounding or other regions. Two transmission mechanisms will be discussed. One is the spatial spillover of industrial green technology. Because there are frequent personnel and capital flows between regions which have geographical proximity, similar structure or relatively close economic ties, it is easier to form spatial diffusion of industrial green technology or organizational modes between regions. The other one is the spatial transference of pollution-intensive industries. If the industrial sectors of one regions try to get greener and cleaner development, the existing local pollution-intensive industries should either invest greatly in pollution treatment and technological upgrading or transfer to other areas which have weaker regulation. The size and direction of final spatial effect depend on the interaction of positive and negative aspects. If the technology diffusion effect is stronger, then the industrial green development in one region will form positive spatial spillover effect, otherwise spatial negative externalities.

The industrial green development of a region is not just influenced by local environmental regulation, but also influenced by the regulation of other regions. As a result, local government may be inclined to reduce the implementation intensity of environmental regulation to attract foreign capital inflows and promote economic growth. A lot of studies have confirmed that there exists spatial effect in environmental regulation of local government. So, it is very necessary to introduce spatial factors into the evaluation of China's environmental regulation effects.

3. Research Models and Methods

This paper constructs an econometric model to evaluate the effects of Chinese local environmental regulation. The basic model is a linear equation about the influence of environmental regulation on Chinese industrial green development. A spatial Durbin panel data model (SDPDM), which simultaneously reflects the characteristics of spatial heterogeneity and competition, will be adopted to accurately examine the effect of China's environmental regulation.

According to the construction method of spatial Durbin model proposed by LeSage and Pace[6], the spatial Durbin equation of the research model is set as:

$$GD = \rho \sum_j W_{ijt} GD_{jt} + \delta \sum_j W_{ijt} ER_{jt} + \kappa ER_{it} + \beta Z_{it} + \gamma \sum_j W_{ijt} Z_{jt} + \mu_i + \lambda_t + \varepsilon_{it}$$

Therefore, coefficient k is used to determine the impact of China's environmental regulation on region while d refers to the spillover effects of regional environmental regulation, which comprehensively reflects the implementation effect of environmental regulation.
The regional industrial green development indicators can be expressed as:

$$GD_{it} = IGR_{it} * GTFP_{it}$$

6 J. P. LeSage, R. K. Pace, "The Biggest Myth in Spatial Econometrics", *Econometrics*, vol.2, no.4, 2014, pp. 217-249,

Among the industrial green development indicators, the key is the growth of green total factor productivity ($GTFP_{it}$). This paper adopts the Malmquist-Luenberger (GML) productivity index based on directional distance function (DDF) to estimate the growth of provincial industrial green total factor productivity.

On the basis of the production possibility frontier, directional distance function can be used to calculate the distance between each decision-making units of production and production possibility frontier, namely relative efficiency. The specific form of directional distance function is expressed as:

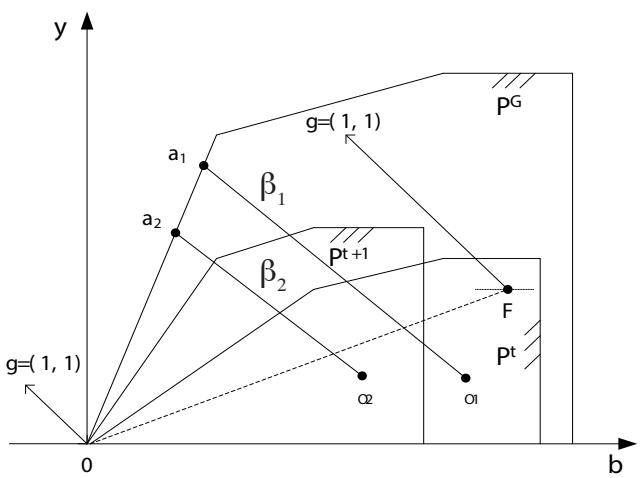
$$D(x,y,b;g) = \max\{\beta:(y,b) + \beta g \in P(x)\}$$

The gross Malmquist-Luenberger (GML) productivity index is defined as:

$$GML^{t,t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = \frac{1 + D^G(x^t, y^t, b^t)}{1 + D^G(x^{t+1}, y^{t+1}, b^{t+1})}$$

Figure 1 shows the geometric representation of gross Malmquist-Luenberger (GML) productivity index. P^G, P^t and P^{t+1} represents the production possibilities sets of gross, period t and period t+1. o_1 and o_2 respectively represent the input - output of decision-making units (DMU) in period t and period t+1. o_1a_1 and o_2a_2 are the distance to gross production technology frontier following distance g. Obviously, compared with o_1, in similar desirable output, the undesirable output of o_2 decreases. Therefore, the green total factor productivity of DMU increases. Traditional Malmquist-Luenberger (ML) productivity index uses geometric mean to measure total factor productivity.

Fig. 1 Geometric representation of gross GML productivity index measurement



4. Measurement of Environmental Regulation Intensity and Setting of Spatial Weight Matrix

This paper constructs a composite index to measure regional environmental regulation intensity. Selecting the emission of industrial SO_2, COD and industrial smoke (dust) to construct the index of environmental regulation intensity:

$$ER_{it} = \frac{1}{3}\sum_{j=1}^{3}\left(p_{ij} \Big/ \frac{1}{30}\sum_{i=1}^{30} p_{ij}\right)$$

This paper proposes 3 spatial weigh matrix. (1) Geographic adjacency weight W^G. (2) Weight of economic development level W^E. (3) Geographic and economic adjacency weight W^{GE}.

5. Spatial Relationship Test and Model Explanation

This paper adopts Moran index to test the spatial correlation of China environmental regulation, and the results is shown in Table 1. It can be found that in three kinds of spatial weights, China environmental regulation rejects the null hypothesis that there isn't spatial correlation at 1% significance level. What's more, as Moran index is greater than zero, the regional regulation in China is not randomly distributed, but has some positive spatial dependence. Therefore, the analysis should not be carried out by traditional measurement methods, but with the aid of spatial econometric analysis tools.

Tab.1 Spatial correlation test results of China environmental regulation

Types of spatial weights	W^G	W^E	W^{GE}
Moran'I	0.477	0.500	0.439
Moran'I z-Statistic	15.098	14.601	8.945
p-value	0.000	0.000	0.000

This paper further carries out spatial error and spatial lag selected LM test to analyze the residuals of OLS regression, the results are shown in Table 2. The results show that in geographic adjacency weights (W^G) the Morgan index of OLS residual is not significant. However, in economic development level weights (W^E) and geographic and economic adjacency weight (W^{GE}) the Morgan index is significantly positive.

Tab. 2 Spatial error and spatial lag model test results of OLS residuals

Types of spatial weights	W^G	W^E	W^{GE}
Spatial error Maron'I test	1.173	143.069***	1202.130***
Spatial error LM test	17.731***	3.650*	5.961**
Spatial error Robust LM test	22.791***	6.249**	11.418***
Spatial lag LM test	0.294	2.490	3.797*
Spatial lag Robust LM test	5.354***	5.090**	9.254***

Notes: ***,** and * respectively represent significance level of 1%, 5% and 10%.

According to the test results of spatial relationship above, this paper selects Spatial Durbin Panel Data Model (SDPDM) to further analyze the data. In order to estimate the two effects of explanatory variables, this paper uses the concepts of average total effect, average direct effect and average indirect effect to assume a spatial Durbin model:

$$y = \sum_{r=1}^{k} S_r(W)x_r + (I_n - \rho W)^{-1}\omega$$

Therefore, the average indirect effect is measured by the total effect of explanatory variable change in one region minus the direct effect of the region. It reflects the sum of effects on other regions, namely spatial spillover effects. For simplicity, average total effect, average direct effect and average indirect effect are expressed by total effect, direct effect and indirect effect.

6. Empirical Results and Robust Test

This paper firstly estimates traditional panel regression equation without spatial factors, the regression results show significant area effects and time effects. In order to further determine whether the area effects and time effects are fixed or random, it should estimate the random effect and fixed effect from the perspectives of space and time and then select estimation models based on Hausman test. The test value of Hausman test is 42.54 and p = 0.000, significantly rejects the null hypothesis that differences of estimated coefficient is non-systematic, indicating that spatial fixed effect model should be applied. At last, this study carries out Wald test to the parameter estimation of spatial fixed effect Durbin model so as to determine whether the model can be simplified as spatial lag model or spatial error model. The p value of Wald test is less than 0.01, which significantly rejects the null hypothesis that the model can be simplified.

According to the empirical results of environmental regulation effect, this paper finds that although the overall environmental regulation in China has played a positive role, this effect is mainly from the spatial spillover effect between regions. The environmental control does not make a desired effect in the local region, but has a positive role in other regions. Or conversely speaking, the environmental regulation effect of the region is not significant, but significantly influenced by the positive spillover of other regions. The total effect is significantly positive. So, the direct effect of local region does not achieve positive effect of environmental regulation. On the one hand, it may be due to China environmental regulation not making a positive effect on the control of industrial pollution emissions. In order to ensure sustainable economic growth and stable revenue sources, local government may be inclined to relax executing intensity, resulting in industrial pollution cannot be effectively mitigated and controlled. On the other hand, China environmental regulation may impede enterprise technological innovation, thus the positive effect on promoting industrial growth fail to emerge. So, it requires governments to design better and more rational environmental regulation tools.

Although the local effect of China's environmental regulation is not valid, it has a positive spillover effect on the neighboring regions or regions with similar economic development level. The local regions can obtain the benefits of "free riding" from the environmental regulation of other regions.

Finally, this paper carries out robust test to the empirical results obtained above. The robust test applied in this paper is to replace the level in current period (represented by ER (-1)) with lag 1 environmental regulation intensity, so as to reflect the lagging quality of environmental regulation effect. It can be known that, the regression results of robust test are basically the same as the results of spatial Durbin Model, indicating that the total effect of China's environmental regulation is positive. However, the effect on local region is not significant, while it has a positive spillover effect on other regions.

7. Conclusion and policy implications

Environmental regulation is not only government's action to solve environmental problems, but also an important driving force for economic development mode transformation and sustainable development. The empirical results of spatial Durbin model show that although China's environmental regulation has significant positive impact on the overall industrial green development, this effect is mainly derived from spatial spillover effects between regions and the environmental regulation of local region does not play an effective role. Local industrial green development does not have significant positive spillover effect on other regions, but negative spatial effect. The robust test with lag 1 environmental regulation intensity as a proxy variable also significantly supports the conclusion. What's more, generally, enterprise scale, industrial capital intensity and industrial R & D are conducive to regional industrial green development, while property construction and foreign trade have negative effects, and the promotion effect of foreign direct investment is not significant.

The conclusions of this paper have important policy implications for environmental regulation such as environmental governance and environmental institutional reform in China. It is still difficult to assess green GDP and there is no successful experience to learn from. This paper suggests using the product of industrial economic growth and green total factors productivity to represent regional green development indicator so as to simultaneously reflect growth and quality. Although the estimation effect of this indicator demand to be further testified, it still can be an important reference for current China's environmental regulation and local green development evaluation.

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Ванг Пенг

Студија о процени ефеката регулатива у области животне средине у Кини: просторна перспектива заснована на индустријском зеленом развоју

Апстракт

На основу свеобухватног схватања зеленог раста и ефикасности овај рад конструише мерење индустријског зеленог развоја у Кини и усваја просторни Дурбин модел за анализу панелних података провинцијског индустријског сектора током 1998. и 2012. године, са циљем емпиријског тестирања ефекта регулатива о животној средини у Кини узимајући у обзир просторни утицај регионалне регулативе о животној средини. (1) Утврђено је да су кинеске регулативе о заштити животне средине значајно ефикасне за индустријски зелени развој у целини. Међутим, регионална еколошка регулатива ефикасно промовише не само индустријски зелени развој региона, већ има значајне позитивне ефекте на друге регије. Дакле, ефикасност целокупне регулативе у области животне средине у Кини углавном је одређена ефекатима просторног преливања из других региона. (2) Индустријски зелени развој у региону може се прениети кроз индустрију која је интензивни загађивач, тако има негативан просторни утицај на индустријске секторе других подручја. (3) Величина предузећа, интензитет индустријског капитала и индустријске иновације помажу у промоцији регионалног индустријског зеленог развоја, док власничка структура и спољна трговина играју неповољну улогу. Штавише, ефекат промовисања страних директних инвестиција није значајан.

***Кључне речи**: Регулатива заштите животне средине, индустријски зелени развој, просторни Дурбин модел*