Research on the Influence of Environmental Regulation on the Efficiency of Green Economy in China

Xiaoqing Bi, Pu Liu *

School of Management, Tianjin University of Technology, Tianjin, China

*Corresponding author e-mail:814834270@qq.com

Abstract. In this paper, the Super-SBM model is used to measure the green economy efficiency of 29 provinces considering non-expected output. The impact of environmental regulation on green economy efficiency is different. There is obvious positive auxiliary effect in the eastern region, and the performance in other regions is not obvious. In order to verify the existence of the Porter hypothesis, a panel model was used to analyze the impact of environmental regulation on the efficiency of the green economy. The results show that environmental regulation plays a role in promoting the efficiency of green economy. The two have a “U”-type relationship. The effect of environmental regulation on green economy efficiency has the effect of promoting re-inhibition.

1. Introduction
In recent years, resource consumption has been excessive, and environmental carrying capacity has approached the upper limit. Reasonable and effective environmental regulation is an important means to solve environmental pollution. A large number of literatures study the relationship between environmental regulation and economic efficiency from different angles, but the promotion of environmental regulation still hinders the efficiency of green economy, and the academic community has not yet reached a consensus. Xie Zhong et al. (2013) [1] empirically analyzed the environmental regulation quadratic model that environmental regulation has a significant negative effect on economic growth. Song Malin et al. (2013) [2] examined the environmental efficiency of China's regional environment, and decomposed it into technical factors and environmental regulation factors by SBM-DEA method. The results show that environmental regulation has a positive effect on environmental efficiency. Therefore, under the premise of sustainable development, consider the actual situation of China's green economy efficiency to promote the coordinated development of regional economies, study the green economy efficiency of undesired output, and the impact of environmental regulation on the efficiency of green economy. The development and formulation of environmental regulation policies is of great significance.

2. Measurement and Analysis of Green Economic Efficiency
Qian Zhengming (2013) [3] defines green economy efficiency as the final economic efficiency after considering the negative effects of economic growth on regional resources and the environment based on the existing economic efficiency. Green economy efficiency not only reflects the coordination
between economic growth and ecological environment in a region, but also measures the rationality of economic growth in the region.

2.1. Measure Model
This paper measures the efficiency of green economy based on the SBM model proposed by Tone [4]. Suppose each province is regarded as a decision unit, there are n decision units DMU (j=1, 2, ..., n), each decision unit has m inputs, recorded as x=(x_1,...,x_m); There are q outputs, denoted as y=(y_1,...,y_q); There are w undesired outputs, recorded as b=(b_1,...,b_w). Then the input and output values of the tth period of the jth province are expressed as (x_{jt}, y_{jt}, b_{jt}). Production possibility set is:

\[ P_t = \{(x_{jt}, y_{jt}, b_{jt}) | \sum_{j=1}^{n} x_{jt} \lambda_{j}^{x} \leq \sum_{j=1}^{n} y_{jt} \lambda_{j}^{y}, \sum_{j=1}^{n} b_{jt} \lambda_{j}^{b} \geq \sum_{j=1}^{n} x_{jt}^{0} \lambda_{j}^{x}, \sum_{j=1}^{n} y_{jt}^{0} \lambda_{j}^{y}, \sum_{j=1}^{n} b_{jt}^{0} \lambda_{j}^{b} \geq 0, \forall m, q, w \} \] (1)

Based on Tone's research, the undesired outputs were included in the model, and the Super-SBM model was constructed as follows:

\[ \min \rho^{*} = \min \frac{1}{m} \sum_{j=1}^{n} x_{jt} \lambda_{j}^{x} \] s.t. \[ \begin{align*}
\sum_{j=1}^{n} \lambda_{j}^{x} x_{jt} & \leq \bar{x} \\
\sum_{j=1}^{n} \lambda_{j}^{y} y_{jt} & \geq \bar{y} \\
\sum_{j=1}^{n} \lambda_{j}^{b} b_{jt} & \geq \bar{b} \\
\lambda & \geq 0, \bar{x} > x_{jt}, \bar{y} > y_{jt}, \bar{b} > b_{jt}, \bar{y} > 0.
\end{align*} \] (2)

In the above formula, \( \bar{x}, \bar{y}, \bar{b} \) refers to the slack variable of input, expected and undesired output. \( \lambda_{j} \) is expressed as a weight vector. If the above equation satisfies \( \sum_{j=1}^{n} \lambda_{j} = 1 \), it means variable scale return (VRS), and instead returns to scale return (CRS). The larger the objective function \( \rho^{*} \), the higher the green economy efficiency.

2.2. Indicator Selection and Data Description
This paper selects the data of 29 provinces (autonomous regions and municipalities) from 2000 to 2016 (excluding Taiwan, Hong Kong, Macao, Tibet and Chongqing) to study the efficiency of green economy. The data mainly comes from the China Environmental Statistics Yearbook and Chinese cities. Statistical Yearbook, etc.

The input variables mainly use energy input, labor input and capital investment. The employment situation at the end of each province is taken as the labor input index; the labor input is expressed as the number of employees at the end of the year; the total stock of each province in the past years is used as the capital input indicator. The expected output is the GDP of the region to weigh the actual state of the economy in the region. Undesired output selects industrial wastewater, solid waste and industrial waste gas.
Table 1. Average value of regional green economy efficiency in China (2000-2016)

| Province       | Green economy efficiency | Province       | Green economy efficiency |
|----------------|--------------------------|----------------|--------------------------|
| Beijing        | 0.9578                   | Tianjin       | 0.7857                   |
| Hebei          | 0.6403                   | Shanghai      | 0.9671                   |
| Jiangsu        | 0.9616                   | Zhejiang      | 0.8682                   |
| Fujian         | 0.8102                   | Shandong      | 0.8042                   |
| Guangdong      | 0.8535                   | Hainan        | 0.4476                   |
| Shanxi         | 0.3684                   | Anhui         | 0.6456                   |
| Jiangxi        | 0.7804                   | Henan         | 0.7331                   |
| Hubei          | 0.6767                   | Hunan         | 0.6894                   |
| Neimenggu      | 0.7531                   | Guangxi       | 0.6032                   |
| Sichuan        | 0.7419                   | Guizhou       | 0.5614                   |
| Yunnan         | 0.5492                   | Shandong      | 0.8271                   |
| Gansu          | 0.6075                   | Qinghai       | 0.3847                   |
| Ningxia        | 0.3847                   | Xinjiang      | 0.5887                   |
| Liaoning       | 0.6341                   | Jilin         | 0.6782                   |
| Heilongjiang   | 0.5875                   | Average value | 0.6858                   |

2.3. Analysis of Green Economic Benefits

As can be seen from Table 1, the green economy in the eastern region (Beijing, Tianjin, etc.) is highly efficient and stable, reaching around 0.95. It shows that the negative effect of environmental pollution is less than the positive economic increase effect. In the western region (Xinjiang, Qinghai, etc.), the overall green economy efficiency is low, and the average value does not reach 0.5, which is directly related to the expected low output during the measurement period. The environmental cost investment is large but the economic benefits are not obvious. The gap between the eastern and western regions is mainly due to the relatively high input and output of the tertiary industry in Jiangsu and other regions. The unanticipated output is very low. The investment in the primary industry in the western region is high, but the undesired output pollution is more serious. The innate geographical location and policy advantages of the eastern region, even if there are environmental pollution problems, but can solve problems through advanced technology and new energy development. In order to improve the efficiency of the green economy, it is necessary to adapt to local conditions, increase the expected output to reduce undesired output, and reduce emissions of pollutants and pollutant gases.

3. Panel Data Model

This paper refers to the relevant literature of previous scholars to study the impact of environmental regulation on the efficiency of green economy. The green economic efficiency of the above calculation is taken as the explanatory variable, and the environmental regulation is used as the explanatory variable. The following measurement model is adopted:

$$ GEE_{it} = \alpha_0 + \alpha_1 \ln ER_{it} + \alpha_2 IND_{it} + \alpha_3 FDI_{it} + \alpha_4 EDU_{it} + \alpha_5 URBAN_{it} + \varepsilon_{it} $$

Among them, i indicates the province; t indicates the year; GEE indicates the green economy efficiency; ER indicates the environmental regulation; IND indicates the industrial structure; FDI indicates the foreign direct investment; EDU indicates the education expenditure; URBAN indicates the urbanization level; \( \varepsilon_{it} \) indicates error.

3.1. Variable Selection and Data Processing

This paper selects the annual data from 29 provinces (cities, districts) in China from 2000 to 2016 to study the impact of environmental regulations on China's green economy efficiency. Among them, the explanatory variable is green economic efficiency, and the core explanatory variable is mainly
environmental regulation. Drawing on the relevant research of Han Yonghui et al. [5], the following variables were selected: Industrial structure: The proportion of the total output value of the secondary industry to GDP indicates that the green economy is less efficient when the pollution of the secondary industry is severe; Foreign direct investment: The proportion of FDI in GDP indicates that the expected results are uncertain; Education expenditure: The proportion of fiscal expenditure on education as a percentage of GDP indicates that the expected result is favorable; Urbanization: The proportion of the population of each province to the total population indicates that the large-scale growth of the urbanized population will affect the efficiency of the green economy.

3.2. Analysis of Empirical Results

The regression analysis of fixed and random effects of the above model using STATA12.0 is shown in Table 2. The analysis shows that environmental regulation plays a role in promoting the efficiency of green economy. The result confirms the existence of Porter's hypothesis. Every 1% increase in ER_{it}, GEE_{it} increases by an average of 0.413%. Therefore, in the future development, we should pay attention to the formulation and implementation of environmental regulation policies to improve the efficiency of the green economy. The industrial structure and the green economy efficiency are negatively correlated. The coefficient of foreign direct investment is positive, which is significant at 5%, and the results are positively correlated. Education expenditure also plays a role in promoting the efficiency of green economy, but it is not obvious, indicating that the level of education needs to be improved. In the future development, attention should be paid to improving the quality of education.

| Table 2. Return of environmental regulation to green economy efficiency |
|---------------------------------------------------------------|
| **Explanatory variable** | **Fixed effect** | **Model 2** | **Hybrid OLS** |
|-------------------------|-----------------|--------------|----------------|
| ER_{it}                 | 0.413***        | 0.62***      | 0.202***       |
|                         | (1.85)          | (2.98)       | (8.46)         |
| IND_{it}                | -0.016***       | -0.017***    | -0.015***      |
|                         | (-4.30)         | (-4.45)      | (-4.25)        |
| FDI_{it}                | 0.823***        | 1.2360***    | 4.2016***      |
|                         | (2.21)          | (3.30)       | (9.85)         |
| EDU_{it}                | 0.9378          | 0.8773       | 0.8835         |
|                         | (1.34)          | (1.24)       | (0.80)         |
| URBAN_{it}              | -0.92           | -1.71        | -1.9           |
|                         | (-1.91)         | (-1.70)      | (-1.90)        |
| .cons                   | 0.2143***       | 0.1378       | -0.4767***     |
|                         | (2.66)          | (0.12)       | (-4.52)        |
| Test statistics         | Prob>F=0.0000   | Prob>chi2=0.0000 | F(5.413)=74.77 |
|                         | Hausman Test    | chi2=25.36   | Prob>chi2=0.0001 |

Note: *, **, and *** indicate significant levels at 10%, 5%, and 1%, respectively.

3.3. Test of Nonlinear Relations

Some recent studies have shown that environmental regulation has a nonlinear relationship with green economy efficiency. Shen Neng [6] believes that the relationship between environmental regulation intensity and environmental efficiency is consistent with the inverted "U" relationship. Use the following model to verify:

\[
GEE_{it} = \alpha_0 + \alpha_1 (\ln ER_{it})^2 + \alpha_2 IND_{it} + \alpha_3 FDI_{it} + \alpha_4 EDU_{it} + \alpha_5 URBAN_{it} + \epsilon_{it} \quad (4)
\]
Table 3. Nonlinear relationship test of environmental regulation on green economy efficiency

| Explanation variable | Fixed effect | Model 1 | Hybrid OLS |
|----------------------|-------------|---------|------------|
|                      | Fixed effect | Random effect | Hybrid OLS |
| ER<sub>it</sub>      | 0.3513**    | 0.3606** | 0.4103     |
|                      | (2.23)      | (2.36)  | (1.45)     |
| (lnER<sub>it</sub>)^2 | -0.0455***  | -0.0440*** | -0.0287*** |
|                      | (-2.06)     | (-1.98) | (-0.70)    |
| IND<sub>it</sub>     | -0.027***   | -0.037*** | -0.018***  |
|                      | (-4.55)     | (-4.34) | (-4.20)    |
| FDI<sub>it</sub>     | 0.6756**    | 1.090*** | 4.2049***  |
|                      | (1.81)      | (2.98)  | (9.84)     |
| EDU<sub>it</sub>     | 0.5987      | 0.5471  | 0.7186     |
|                      | (0.81)      | (0.74)  | (0.62)     |
| URBAN<sub>it</sub>   | -1.68       | -1.81   | -1.89      |
|                      | (-1.90)     | (-1.60) | (-1.90)    |
| .cons                | -0.3179     | -0.3832 | -0.8125*   |
|                      | (-1.21)     | (-1.37) | (-1.66)    |
| Test statistics      | Prob>F=0.0000 | Prob>chi2=0.0000 | Prob>F=0.0000 |
|                      | F(29.384) = 50.35 | F(6.413) = 62.40 |            |
| Hausman Test:chi2(8) | 24.16       | Prob>chi2=0.0005 |

Note: *, **, and *** indicate significant levels at 10%, 5%, and 1%, respectively.

The above $(\text{ln} \, \text{ER})^2$ represents the squared term of the environmental regulation, and the other variables have the same meaning as Model 1. The regressions all passed the significance test, indicating that the regression is reasonable. As can be seen from Table 3, there is a non-linear relationship between environmental regulation and green economy efficiency, which confirms the inverted “U” type relationship, which first promotes post-inhibition and is significant at 5%. Other factors are consistent with the analysis results of Model 1, and it is significant at 1%, 5%, and 10%, respectively. Education has a positive effect on GEE<sub>it</sub> but it is not obvious. It is necessary to strengthen education. In short, environmental regulation is positively related to the efficiency of the green economy. The implementation of environmental regulation must be tailored to local conditions, not too strict, the benefits are reduced, pollution is increased, and counterproductive.

4. Conclusions and Recommendations

In this paper, the Super-SBM model is used to measure the green economy efficiency based on undesired output. It is found that the overall green economy efficiency in the eastern region is high and stable, followed by the central region and the western region. To improve the efficiency of the green economy, it is necessary to adapt to local conditions. Strengthen support for the central and western regions, increase expected output to reduce undesired output, and reduce emissions of pollutants and pollutant gases.

In order to investigate whether the impact of environmental regulation on green economy growth is promoting or inhibiting, this study empirically tests the relationship between environmental regulation and green economy efficiency. The results show that China's environmental regulation has a positive effect on the efficiency of green economy, and it has a "U"-type relationship. The Bohr hypothesis does exist. Therefore, in order to improve the efficiency of green economy in various regions, we must control the intensity of environmental regulation. It should not be too strict. Otherwise, the government should encourage enterprises to adjust their industrial structure, innovate green technologies, improve the efficiency of green economy, and promote green economy growth.
References

[1] Xie Zhong, Zhang Xianfeng, Lu Dan. Natural resource endowment, environmental regulation and regional economic growth [J]. Jianghuai Forum, 2013 (06): 61-67.

[2] Song Malin et al. Fiscal Decentralization, Environmental Regulation and Green Total Factor Productivity [J]. Scientific Decision, 2017(09): 65-92.

[3] Qian Zhengming, Liu Xiaochen. Research on Regional Difference and Convergence of Green Economy Efficiency in China [J].Journal of Xiamen University(Philosophy and Social Sciences),2014(01):110-118.

[4] Kaoru Tone. A slacks-based measure of super-efficiency in data envelopment analysis[J]. European Journal of Operational Research,2002,143(01):32-41.

[5] Han Yonghui, Huang Liangxiong, Wang Xianbin. Does industrial structure upgrade improve ecological civilization? [J]. Finance and Trade, 2015, 36 (12): 129-146.

[6] Shen Neng. Research on the Mechanism of Green Innovation Efficiency and Key Factors in China from the Perspective of Technology Heterogeneity: Based on Hybrid DEA and Structured Equation Model [J]. Journal of Industrial Engineering and Engineering Management, 2018, 32(04): 46-53.