Study on Grey Relational Degree between Environmental Regulation, FDI and Carbon Emission Intensity in the Yangtze River Delta Region

Qianqian Xiao[1, a], Hang Yuan[1, b], and Xiaoke Zhao[2, c, *]

[1]School of Business Administration, Hohai University, Changzhou, China

[2]School of Business, Changzhou University, Changzhou, China

[a]xqqhenggaoxing@163.com, [b]1017802597@qq.com, [c]463535628@qq.com

*Corresponding author

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Abstract: Reducing carbon emissions can effectively curb the global warming and promote sustainable development. Based on the relevant data of Yangtze River Delta region from 2012 to 2016, the paper calculates the carbon emission intensity in Shanghai, Jiangsu Province, Zhejiang Province and Anhui Province over the years. The paper also empirically tests the correlation between environmental regulation, FDI and carbon emission intensity in three provinces and one city through the establishment of grey relational analysis model. The results show that the effect of carbon emission reduction is obvious in the Yangtze River Delta region, and the carbon emission intensity decreases year by year. The correlation degree between environmental regulation, FDI and carbon emission intensity is different between provinces and cities. The correlation degree between environmental regulation and carbon emission intensity is higher in Anhui Province, and the correlation degree between FDI and carbon emission intensity is higher in other provinces and cities. In order to reduce carbon emissions, it is necessary to coordinate the use of environmental regulation tools and give full play to the role of FDI in the optimization of industrial structure.

1. Introduction

According to the years of monitoring of the CGAWBO Warri Guanshan Base, since 2000, the concentration of carbon dioxide in the atmosphere has increased by 2.5ppm per year (1ppm means that one million air molecules contain one carbon dioxide molecule), which is a large increase. The global greenhouse gas emissions situation is still grim, and the global warming trend is not decreasing. Research firm Carbon Brief estimates that China’s carbon emissions totaled 10 billion tons in 2018, accounting for more than a quarter of the world’s total carbon dioxide emissions, making it the country with the largest carbon emissions in the world. Under the framework of the Paris Agreement, China has proposed a “double-constrained” voluntary contribution target that peaks in carbon dioxide emissions by 2030 and carbon intensity declines by 60% to 65% compared to 2005. The National 13th Five-Year Plan also proposes the goal of achieving an overall improvement in the quality of the ecological environment. It is necessary to achieve a green and low-carbon level of production methods and lifestyles. In the face of increasing international focus on carbon emission reduction, how to achieve carbon emission reduction targets in China has become an urgent issue. The Yangtze River Delta region, including Shanghai, Jiangsu, Zhejiang, and Anhui provinces, is the most comprehensive economic center in China. With the rapid economic development, the resources and environment are under tremendous pressure, and the per capita carbon emissions are higher than the national average level in this region. Exploring the relationship between related factors and carbon emission intensity in the Yangtze River Delta region plays an important role in formulating governance policies to control their carbon emission intensity, and is also important for achieving the overall low-carbon development goals.

2. Review of documents

As the global greenhouse gas emissions situation becomes more severe and the global warming trend continues unabated, the academic research on carbon emissions continues to deepen. In 1999, Mielnik, O. uses carbonization index (carbon/energy) to assess climate change evolution patterns in industrialized and developing countries [1]; in order to reflect common and differentiated responsibilities, in 2002, Guoyu Ren proposed the concept of cumulative emissions of carbon dioxide per capita [2]; in 2005, Sun uses carbon emission intensity to measure carbon emissions performance [3].

Frederick van der Ploeg supports the “green paradox” effect, which means environmental regulations is positively related to carbon emissions [4]. Some scholars support the “reverse effect”. Juan Tan analyzed China’s carbon emissions data and the total government investment in pollution control in 1990-2010, and concluded that environmental regulation has a restraining effect on carbon emissions [5]. In 2017, Min Wang found that the impact of environmental regulation on carbon emissions shows an inverted “U” type trend, with a “green paradox effect” before the inflection point and a “reverse effect” after the inflection point [6]. Most of the theoretical mechanisms of research follow the theoretical framework of Grossman and Krueger (1991) to examine the effects of FDI on carbon emissions in terms of scale, technology, and structure. For example, based on the data from 2001 to 2016, Rong Wang verified the different effects of FDI on carbon emissions in the eastern, central and western regions of China by using the systematic GMM method. The results show that the FDI scale effect can reduce carbon in the east of China; the FDI technology effect has a negative effect on carbon emissions in the east and central regions of China, and a positive effect on the western region of China; the FDI structural effect has a negative effect on the carbon emissions in the eastern China, and a positive effect on the carbon emissions in the central and western regions [7].

Based on the total CO_2 emissions data of Tunisia from 1990 to 2006, M’raihi used the LMDI method to analyze the average carbon dioxide emissions of fossil fuels in Tunisia. The results show that economic growth is the main factor driving the growth of carbon dioxide emissions [8]. There are also many scholars who combine measurement methods with model diversification to analyze factors affecting carbon emissions. Shahbaz used the STIRPAT model to analyze the impact of urbanization on carbon dioxide emissions in Malaysia during the 1970-2011 period [9]. In this paper, grey relational analysis is used to directly measure the degree of correlation among factors in the system, and to determine the grey relational degree between environmental regulations, FDI and carbon emission intensity in the Yangtze River Delta region from 2012 to 2016.

3. The theoretical model

The method chosen in this paper is the grey relational analysis method, created by Professor Julong Deng in 1982. In the process of system development, if the trend of the two factors changes, that is, the degree of synchronous change is higher, it can be said that the degree of correlation between the two is higher; otherwise, it is lower. The grey relational analysis method can measure the degree of correlation among factors in the system according to the similarity or dissimilarity of the development trends among the factors, that is, the “grey correlation degree”.

In the grey relational analysis, the reference sequence reflecting the behavior characteristics of the system and the comparison sequence affecting the system behavior are first determined. Then the reference sequence and the comparison sequence are nondimensionalized, that is, divide respectively all data in the sequences with different units and different initial values by the first data to get a new reference sequence and a new comparison sequence. Let the sequences be:

$$X^{(0)}(k) = \left\{X^{(0)}(1),\ X^{(0)}(2),\ldots,\ X^{(0)}(n)\right\}$$

$$\hat{X}^{(0)}(k) = \left\{\hat{X}^{(0)}(1), \hat{X}^{(0)}(2),\ldots, \hat{X}^{(0)}(n)\right\}$$

The correlation coefficient is defined as:

$$\eta(k)=\frac{\min\min\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|+\rho\max\max\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|}{\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|+\rho\max\max\left|\hat{X}^{(0)}(k)-X^{(0)}(k)\right|}$$

Because the correlation coefficient is the correlation degree between the comparison sequence and the reference sequence at each moment, it has more than one number, and the information is too scattered to facilitate the overall comparison. Therefore, it is necessary to concentrate the correlation coefficients at each moment into one value, that is, to find the average value, as the quantity representation of the degree of association between the comparison sequence and the reference sequence. The average value is the grey correlation degree, r_i.

$$r_i=\frac{1}{n}\sum_{k=1}^{n}\eta_i(k)$$

If r_i closes to 1, the degree of association is high. Finally, rank the grey correlation degree, and the greater grey correlation degree indicates that the relationship between the two is more closely related.

4. Empirical analysis

4.1 Data description

This paper uses the carbon emission formula: carbon emissions= terminal energy consumption × energy conversion standard coal reference coefficient×energy carbon dioxide conversion coefficient according to standard coal [10]. In this paper, the selected terminal energy is mainly 9 kinds of energy with large carbon emissions, namely: raw coal, coke, crude oil, gasoline, kerosene, diesel, raw oil, natural gas, electric power. The energy conversion standard coal reference coefficients come from China Energy Statistics Yearbook (2017) Appendix 4. The coefficients are 0.7143, 0.9714, 1.4286, 1.4714, 1.4714, 1.4571, 1.4286, 1.2150 and 0.1229. Based on the IPCC Guidelines for National Greenhouse Gas Emission Inventory, the energy carbon dioxide conversion coefficients according to standard coal are 0.7559, 0.8550, 0.5857, 0.5538, 0.5714, 0.5921, 0.6185, 0.4483 and 2.2100. According to the total energy consumption of various regions in the China Energy Statistical Yearbook from 2012 to 2016, the total carbon emissions in Shanghai, Jiangsu, Zhejiang and Anhui in 2012-2016 were calculated. Carbon emission intensity refers to the amount of carbon dioxide emitted by each unit of GDP growth. According to the GDP shown in the Statistical Communique of National Economic and Social Development in the above-mentioned regions in 2012-2014, the carbon emission intensity of each region in 2012-2016 can be obtained. In this paper, the FDI indicator is the actual amount of foreign investment released in the Statistical Communique of National Economic and Social Development, and the environmental regulation indicators is the total government investment on pollution control in each region published in the China Environmental Yearbook.

4.2 Empirical results

If a region’s economic growth is accompanied by a decline in carbon dioxide emissions per unit of GDP, it means that the region has achieved a low-carbon development model. According to the communique, the total GDP of the three provinces and one city in the Yangtze River Delta region has increased year by year, and from the perspective of carbon emission intensity, the carbon dioxide emissions per unit GDP in the three provinces and one city have decreased year by year, as shown in Figure 1. This fully shows that the Yangtze River Delta region is moving towards a low-carbon development model. In 2013, the State Council issued the “Air Pollution Prevention and Control Action Plan” in the Yangtze River Delta region to start the joint prevention and control of air pollution, and gradually realize the standards in energy conservation and emission reduction. Government regulation has played a big role in lowering carbon emissions. From the perspective of low carbon, Zhejiang and Shanghai have the highest level of low carbon, followed by Jiangsu Province, and Anhui Province.

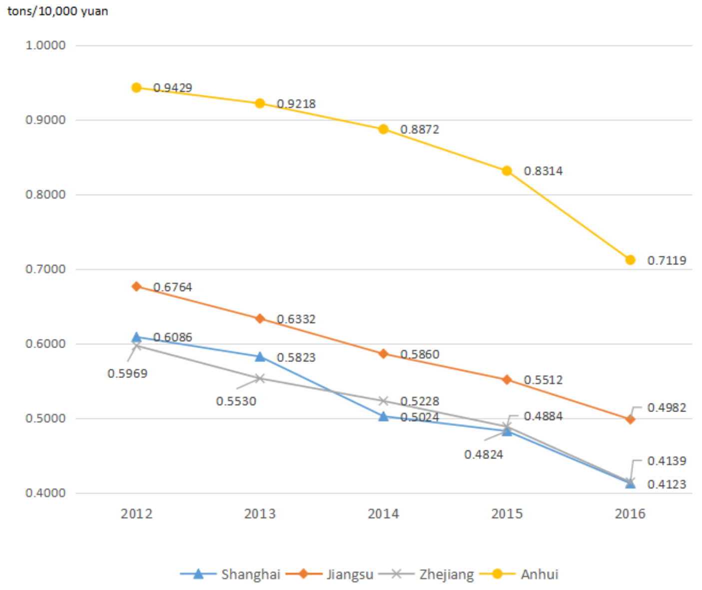

Figure 1. 2012-2016 Yangtze River Delta carbon emission intensity curve

The coefficient of variation is a statistic that measures the degree of variation in the data. The intensity of carbon emissions varies widely across the region, and changes of differences can be measured by the coefficient of variation. Figure 2 shows that the difference in carbon emission intensity of different places reached a peak in 2014, and then the difference gradually narrowed. This is mainly because Shanghai, Jiangsu, and Zhejiang provinces had strong carbon emission reductions before 2014, and Anhui Province had a large gap with them. After 2014, Anhui Province's emission reduction efforts have increased, and the gap has gradually narrowed. Especially in 2016, the carbon emission intensity of Anhui Province has decreased by more than 0.1 tons per 10,000 yuan.

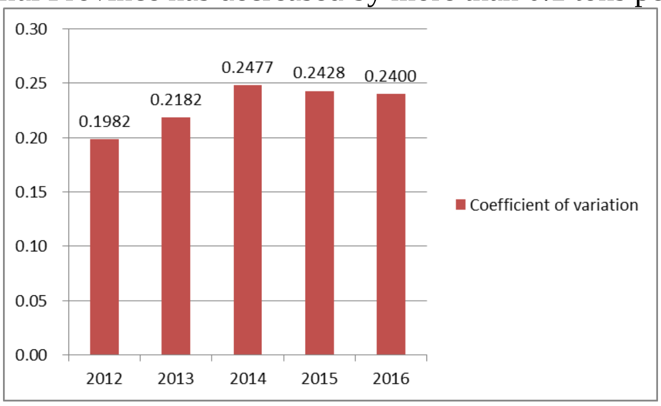

Figure 1. Coefficient of variation

Taking the carbon emission intensity of a certain place in 2012-2016 as the reference sequence, the actual amount of foreign investment in 2012-2016 is the first comparison sequence, and the total government investment on pollution control in 2012-2016 is the second comparison sequence. Through the grey relational analysis method, the grey correlation degrees between environmental regulation, FDI and the carbon emission intensity in each place are obtained (Table 1). The grey correlation degree between environmental regulation and carbon emission intensity is r_1; the grey correlation degree between FDI and carbon emission intensity is r_2. In the table 1, we can see that $r_2 > r_1$ in Shanghai, Jiangsu Province and Zhejiang Province. It explains that their carbon intensity decline is more closely related to FDI. Among them, Jiangsu Province has the highest correlation degree between FDI and carbon emission intensity, close to 0.9. In Anhui Province, $r_1 > r_2$, which indicates that the decline in carbon intensity is more closely linked to environmental regulations in Anhui Province.

Table.1. Grey correlation degrees between related factors and carbon emission intensity in the Yangtze River Delta region in 2012-2016

Province or city	Environmental regulation	FDI
Shanghai	0.5262	0.6808
Jiangsu Province	0.5199	0.8776
Zhejiang Province	0.6169	0.6369
Anhui Province	0.6056	0.5954

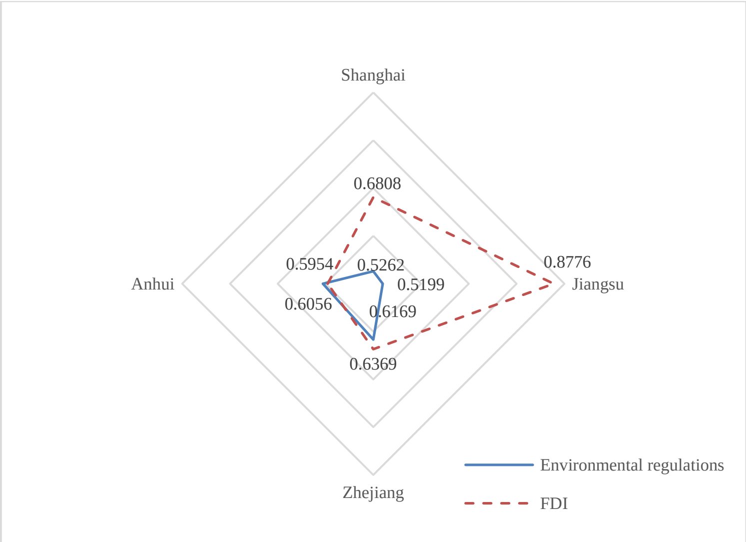

Figure 3. Comparison of grey correlation degrees between related factors and carbon emission intensity in the Yangtze River Delta region in 2012-2016

From figure 3, we can see it clearly that $r_2 > r_1$ in Shanghai, Jiangsu Province and Zhejiang Province and $r_1 > r_2$ in Anhui Province. Although the governments of Shanghai, Jiangsu, and Zhejiang provinces also strictly control pollution, their carbon emission intensity is not as close to environmental regulation as Anhui Province, largely because the proportion of total investment in pollution control in the two provinces and one city is not as high as that of Anhui Province (Figure 4). Take Jiangsu Province as an example, the total carbon emissions in Jiangsu Province and the investment in pollution control are about twice that of Anhui Province, and the GDP is three times that of Anhui Province. This comparison shows the GDP of Jiangsu Province is less dependent on high-pollution, high-energy-consuming, high-emission enterprises. Compared with strict environmental and ecological policies, rationalization of industrial structure and more support for low-carbon industries are paid more attention in Jiangsu Province. Therefore, Jiangsu Province has higher emission reduction efficiency. From the perspective of foreign direct investment, foreign direct investment in Shanghai, Jiangsu and Zhejiang provinces is relatively large. Generally speaking, the tertiary industry absorbs stronger employment, consumes less energy, and is less polluting to the environment. The development of the tertiary industry contributes to green GDP. In the comparison of provincial and municipal industries with foreign direct investment (Figure 5), it is found that the proportion of foreign direct investment in the tertiary industry in Shanghai, Jiangsu and Zhejiang is greater than that in Anhui. And Shanghai, Jiangsu and Zhejiang provinces have invested in more high-tech industries (low-carbon industries). These findings are consistent with Rong Wang's conclusions: the FDI scale effect can reduce carbon emission levels in the east, and the FDI technology effect has a negative effect on carbon emissions in the east, and the FDI structure effect has a negative effect on the eastern carbon emissions.

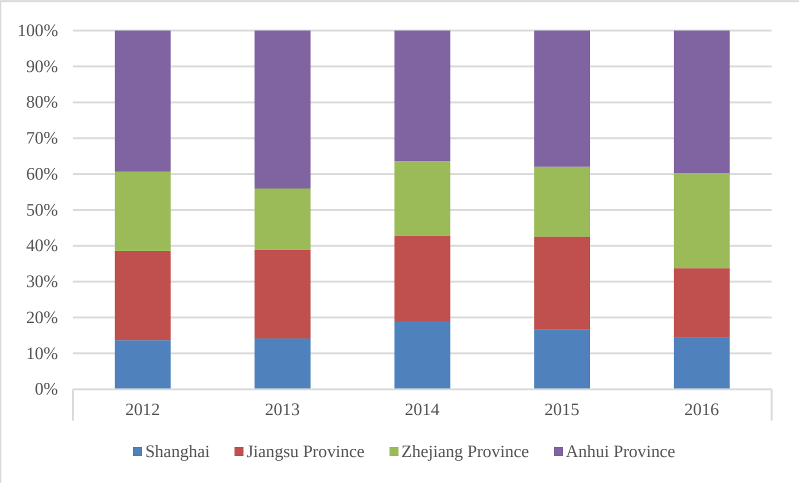

Figure 2. Comparison of environmental regulation intensity (total investment in pollution control / GDP)

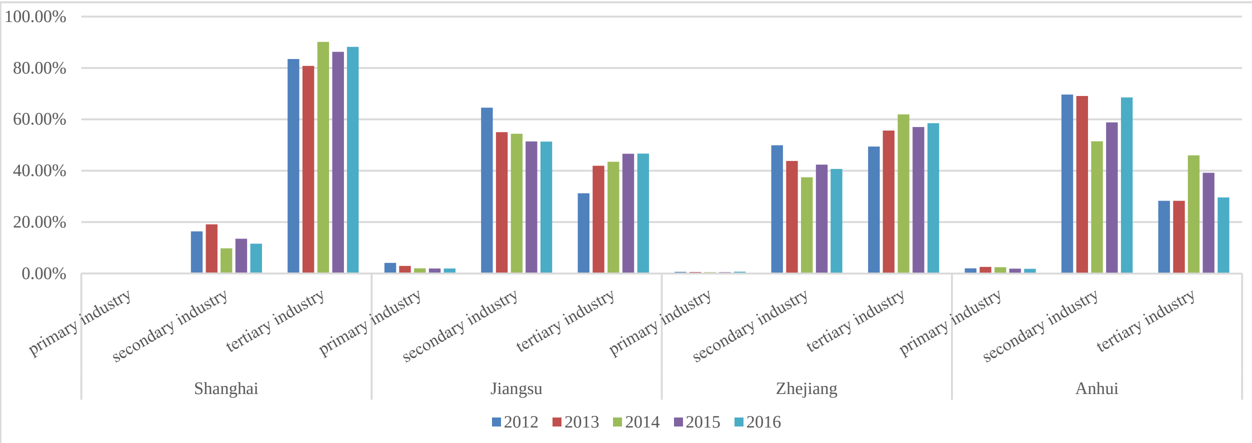

Figure 3. Comparison of industrial structure of FDI in the Yangtze River Delta

5. Conclusions and recommendations

The main conclusions of this study are as follows: first, the carbon emission reduction effect in the Yangtze River Delta region is obvious, and the carbon emission intensity is decreasing year by year. Second, the correlation degree between environmental regulation and the carbon emission intensity of Anhui Province is greater. The correlation degree between FDI and carbon emission intensity is greater in Shanghai, Jiangsu and Zhejiang Province. Anhui Province has a higher proportion of investment in environmental governance. Shanghai, Jiangsu and Zhejiang provinces have performed better in FDI industrial restructuring. Third, Shanghai's carbon emission intensity is the lowest, so shanghai is the foretype in the region. Although Shanghai's pollution control investment accounts the lowest proportion of GDP, Shanghai's industrial structure is more reasonable, and the proportion of high-end industries is more. The proportion of the tertiary industry far exceeds the primary and secondary industry, which has inspired other provinces in the region to continue to promote industrial restructuring and vigorously support the low-pollution, low-emission, low-energy-consuming industries.

Based on the above, the recommendations are as follows: firstly, continue to strengthen the coordinated control of air pollution in the Yangtze River Delta region, accelerate the implementation of common actions for pollution control, and explore the common problems of regional pollution prevention and control; secondly, in Jiangsu, Shanghai and Zhejiang, energy utilization efficiency is higher than the national average level. Therefore, if the three places want to achieve low-carbon development, they should first adjust and optimize the industrial structure, limit the development of high-energy-consuming industries, and vigorously develop the renewable energy industry. Anhui's energy utilization efficiency is lower, so it can reduce carbon emission intensity through technology updates; thirdly, targeted and differentiated investment policy guidance and environmental regulation should be determined according to the environmental pollution and industrial development of each region; fourthly, improve the environmental laws and regulations, resist the "super national treatment" of foreign capital, and enhance the entry barriers of high-carbon industries. Carry out preferential policies for high-quality foreign direct investment, and restrict the introduction of projects that do not meet the carbon emission standards. It is necessary to enhance the contribution of FDI to the sustainable development, and ultimately achieve a low-carbon economic development mode.

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