

Research on Efficiency Evaluation and Influencing Factors of Green Economy Development in Central China

Chang Song

School of Economics and Finance, Chongqing University of Technology, Chongqing 400054, China.

Abstract: Behind decades of rapid economic growth in China is the massive consumption of resources and environmental damage. Since the establishment of China's "dual carbon" goals, it has profoundly influenced the development of green economy in the country. The central region of China plays an important role in carrying out the industrial development process in the eastern region, and the current status of green economy development in the central region has a significant impact on the overall green development. This article evaluates the efficiency of green economy development in 80 prefecture level cities in six provinces in central China from 2012 to 2022 using a super efficiency SBM model that includes unexpected outputs. The results show that the efficiency of green economy development in the central region is gradually improving, and there is an imbalance in development among prefecture level cities. Through the study of its influencing factors, it is found that the level of economic development, industrial structure, education level, financial support, and opening up to the outside world have a significant impact on the development of green economy in the central region.

Keywords: Central region, Green economy, Efficiency.

1. Introduction

Since the implementation of reform and opening up, China's economy has maintained high-speed growth for more than 40 years, and its economic strength has significantly increased, becoming one of the main driving forces for promoting world economic growth. However, behind the rapid economic growth in our country is the extensive development of resources and environmental pollution over the past few decades, which conflicts with the concept of sustainable development that our country needs. In the 2022 Global Environmental Performance Index (EPI) ranking, China ranks 160th, indicating that China's resource and environmental issues are still very prominent on a global scale. The report of the 19th National Congress of the Communist Party of China pointed out that the Chinese economy has shifted from a stage of high-speed growth to a stage of high-quality development, and is currently in a critical period of transforming development mode, optimizing economic structure, and transforming growth drivers. To successfully complete the transformation of China's economic development mode, China must develop a green economy by reducing energy consumption, increasing environmental governance and protection, and balancing the relationship between environmental pollution, resource waste, and economic and social development. The central region spans the Yellow River Basin and some provinces in the Yangtze River Basin, involving six provinces: Shanxi, Henan, Hubei, Hunan, Jiangxi, and Anhui. It spans the north and south, with economically developed coastal areas to the east and underdeveloped inland areas to the west. Due to its advantageous location, the ecology of the central region plays a regulatory role in connecting with the better ecological development in the east and the unfavorable natural environment in the west. Moreover, the central region is home to a large population in China, and its ecological environment development plays an important role in overall ecological

protection and promoting the development of China's regional green economy. So, what is the current situation of green economy development in the central region, and how to improve the level of green economy development in the central region has become an important and urgent research topic. The efficiency of green economic development is an important indicator for measuring the degree of green economic development in a region. What are the factors that affect the efficiency of green economic development? In this context, this article will conduct further research and exploration.

2. Journals Reviewed

In terms of the current research status of green economic development in the central region, Li Xuhui measured the efficiency of green industrial economic development in the five major regions of China and found that the green industrial economic efficiency in the Yellow River Basin and Yangtze River Economic Belt, including the central region, is lower than the average of the five regions [1]. After evaluating the green development efficiency of resource-based cities in the six central provinces, Shi Yufang and others found that none of the six central provinces have reached the forefront of production at the inter provincial level [2]. In addition, numerous scholars have measured the efficiency of green economy nationwide, showing that China's green economy is higher in the east and lower in the west, showing a gradient decline.

There are many related studies in the academic community on the evaluation of the level of green economy development, but there are differences in the emphasis of scholars on constructing evaluation index systems. However, through research, it has been found that the most representative source of indicator construction system is the "China Green Development Index Report" jointly published by Beijing Normal University, Southwest University, and relevant departments of the National Bureau of Statistics. In terms of

researching the construction of efficiency indicators for green economy development, the United Nations Environment Programme's green economy measurement framework is built from three aspects: economic transformation, resource efficiency, social progress, and human well-being [3]. Zhou Huirong and others pointed out that when meeting the green production indicators, we should consider the social production of the economic system and fully consider its position in green national economic activities [4]. Liu Xiu uses input index and output index to measure the green economy. The input index measures the greening of production from the perspective of resource acquisition, while the output index measures the greening of production from the perspective of waste emissions [5]. Wang Hongyi and others constructed indicators to evaluate the development of green economy from the aspects of economic development level, financial development level, foreign investment level, population concentration level, and government intervention level. In terms of constructing the indicator system [6]. He Jing used the "R-clustering grey correlation advantage analysis" method to build a comprehensive and reliable green economy evaluation indicator system [7]. Xue Long used the expert scoring method in subjective weighting to calculate the level of green economic development indicators in Jinan City after weighting them [8]. Zhang Wang et al. used a combination of subjective and objective weighting methods. The subjective weighting method used Analytic Hierarchy Process and expert scoring method, while the objective weighting method used Mean Squared Error and CRITIC methods to weight evaluation indicators and conducted research on low-carbon and green development in Chinese cities [9]. Zeng Xiangang and others used the principal component analysis method in the objective assignment method to process the indicator data and calculate the level of green economic development in China [10]. For the measurement of the level of green economy development, the academic community mostly uses economic development efficiency for evaluation. There are two main methods for measuring the efficiency of green economy development: one is to construct green GDP, which incorporates environmental pollution and the GDP in the original output into the model. The second approach is to incorporate environmental pollution as an unexpected output and a separate output factor into the model (Zhang Haixia.[11]; Chen Yang [12]). From the perspective of research methods, scholars' studies on measuring the efficiency of green economic development mostly rely on non parametric analysis methods such as DEA models. There are relatively few studies on the SFA model using parameter analysis methods. Moreover, in the non parametric analysis method DEA model, most scholars adopt the SBM model in the DEA extended model; For example, Kong Lingzhang used the SBM model to measure the efficiency of regional green development, thereby studying the mechanism of the impact of the digital economy on regional green development [13]. Xu Yijing et al. measured the level of green economic development in Chinese cities characterized by green total factor productivity using the SBM model of unexpected output, and studied the impact of the circulation industry on China's green economic development. In terms of research methods for factors affecting the efficiency of green economy development, there are two aspects: quantitative research and non quantitative research. In non quantitative research [14]. Zhang Wang et al. and Wu Xuxiao et al. determined the impact relationship by

studying the degree of correlation between variables such as Pearson and grey relational analysis [15]. There is still relatively little research on non quantitative research methods of this kind. In terms of quantitative research, Liu Haoran explored the influencing factors by constructing a Tobit regression model [16].

3. Research Models and Indicator Data

3.1. Super Efficiency SBM Index Model

This article focuses on the efficiency evaluation of green economy development in some prefecture level cities, which includes expected and unexpected outputs. Therefore, it is necessary to first construct a production possibility set, which should include input variables, expected output variables, and unexpected output variables. Assuming that the research object has n decision units, m input factors, and s outputs, and the s outputs are further divided into s_1 expected outputs and s_2 unexpected outputs, their corresponding vectors are represented as $x \in R^m$, $y^g \in R^{S_1}$, $y^b \in R^{S_2}$, The input-output matrix is as follows:

$$\begin{aligned} X &= (x_{ij}) \in R^{m \times n} \\ Y^g &= (y_{ij}^g) \in R^{S_1 \times n} \\ Y^b &= (y_{ij}^b) \in R^{S_2 \times n} \\ X > 0, Y > 0 \end{aligned} \quad (1)$$

The set of production possibilities at this time is $P = \{(x, y^g, y^b) | x \geq X\lambda, y \geq Y\lambda, \lambda \geq 0\}$

The above equation (1) is an inequality budget constraint model that includes expected inputs, expected outputs, and unexpected outputs. When $\sum \lambda \neq 1$, the model maintains a constant return to scale. When $\sum \lambda = 1$, the model had variable returns to scale. The SBM model can be expressed as:

$$\begin{aligned} \min \rho &= (1 - \frac{1}{m} \sum_{i=1}^m \frac{S_i^-}{x_{i_0}}) / [1 + \frac{1}{S_1 + S_2} (\sum_{r=1}^{S_1} \frac{S_r^g}{y_{r_0}^g} + \sum_{r=1}^{S_2} \frac{S_r^b}{y_{r_0}^b})] \quad (2) \\ \text{s.t.} &= \begin{cases} x_0 = X\lambda + S^- \\ y_0^g = Y^g \lambda - S^g \\ y_0^b = Y^b \lambda + S^b \\ S^- \geq 0, S^g \geq 0, S^b \geq 0, \lambda \geq 0 \end{cases} \quad (3) \end{aligned}$$

In the above formula (2), s -represents input slack, sg represents expected output slack, sb represents unexpected output slack, and λ represents weight vector. When $\rho=1$ and $s=0$, $sg=0$, $sb=0$, it indicates that the decision unit DMU is effective; When $\rho < 1$, the decision unit DMU is invalid.

Although SBM has to some extent addressed the limitations of traditional DEA models, there is a possibility of multiple decision efficiencies being simultaneously effective when calculating post evaluation efficiency, which is not conducive to comparative analysis of results. On this basis, the super efficient SBM model created by Tone's improvement can effectively solve the problem of multiple

decision units simultaneously being difficult to compare and analyze in the original model.

In summary, this article chooses to use the super efficiency SBM model to measure the research object, including the super efficiency SBM model with unexpected output, as shown below:

$$\min \rho = \frac{\frac{1}{m} \sum_{i=1}^m \bar{x}_i}{\frac{1}{s_1 + s_2} \left(\sum_{r=1}^{s_1} \frac{\bar{y}_r^g}{y_{r_0}^g} + \sum_{r=1}^{s_2} \frac{\bar{y}_r^b}{y_{r_0}^b} \right)}$$

$$s.t. \begin{cases} \bar{x} \geq \sum_{i=1, \neq 0}^n \lambda_i x_i \\ \bar{y}^g = \sum_{i=1, \neq 0}^n \lambda_i y_i^g \\ \bar{y}^b = \sum_{i=1, \neq 0}^n \lambda_i y_i^b \\ \bar{x} \geq x_0, \bar{y}^g \geq y_0^g, \bar{y}^b \geq y_0^b, \lambda \geq 0 \end{cases} \quad (4)$$

The letters in formula (4) represent the same as in (3), and in the super efficient SBM model, the value of ρ may be greater than 1. In addition, the larger the value of ρ , the more effective the DMU.

3.2. Indicator Selection and Data Sources

Through literature review and research, four types of indicators are usually used to calculate the efficiency of regional green economic development: non energy input factors, resource input factors, expected output, and unexpected output. Based on this, the following indicator system is constructed.

3.3. Investment Indicators

Capital investment. This article adopts the calculation method proposed by GoldSmith (1951), which is recognized by relevant scholars in China. The perpetual inventory method is used to calculate the capital stock and measure capital investment. The specific calculation formula is as follows:

$$K_t = (1 - \beta_t) K_{t-1} + I_t \quad (5)$$

Wherein, K_t refers to the capital stock in year t , K_{t-1} refers to the capital stock in year $t-1$, I_t refers to the total fixed assets investment of the whole society in a place in year t (excluding farmers), in which the total fixed assets of the whole society in a region in 2012 were recorded as the capital stock of the year, and β_t refers to the depreciation rate of fixed assets in a region in year t . The research of Zhang Jun [17], a scholar widely recognized in China, determined the asset depreciation rate of the province as 9.6%. Since the research object of this article is prefecture level cities, in the absence of relevant data, this article uses the provincial depreciation rate to replace the depreciation rate of fixed assets in prefecture level cities for calculation. In addition, the amount of fixed assets investment is calculated and counted based on the price of the current year. This paper takes 2012 as the base period, and determines

the actual annual amount of fixed assets investment after processing the amount of fixed assets investment by querying the fixed asset deflator of the corresponding annual fee. The deflator for prefecture level cities is replaced by that province.

Labor input. The number of employees in each prefecture level city at the end of the year was selected to measure labor input.

Energy investment. When searching for data, it was found that the prefecture level cities in the studied area did not disclose coal data. Therefore, this article uses the electricity consumption of the whole society as the energy input indicator.

3.4. Output Indicators

Expected output. This article selects the regional gross domestic product (GDP) of prefecture level cities as the expected output. Using 2012 as the base year, the actual GDP of the region is calculated based on the GDP deflator index of the region. As the deflator index of each city is not publicly available and not suitable to obtain, this article chooses the GDP deflator index of the province instead of that of the prefecture level city for calculation.

Unexpected output. On the basis of ensuring the effectiveness and accuracy of evaluating the efficiency of green economic development to the greatest extent possible, as well as the collectability of data, this article selects three indicators that have an impact on the regional ecological environment, including total industrial wastewater discharge, sulfur dioxide emissions, and industrial smoke emissions, as unexpected output indicators.

3.5. Data Source Explanation

The indicator system selected in this article is shown in Table 1. The relevant data was compiled by the author through databases such as the Statistical Bulletin, China Urban Statistical Yearbook, and Wind published by various prefecture level cities and provinces.

Table 1. Efficiency Evaluation Index System for Green Economy Development

First level indicator	Secondary indicators	Third level indicators
input	capital	Fixed capital stock (10000 yuan)
	labour force	Year end employment population in urban areas (10000 people)
	energy	Total electricity consumption of the whole society (100 million kilowatt hours)
output	expected output	Actual Gross Domestic Product of the Region (in billions of yuan)
	undesirable output	Industrial wastewater discharge volume (10000 tons)
		Sulfur dioxide emissions (10000 tons)
		Industrial dust emissions (10000 tons)

When collecting data, due to the existence of provincial-level cities and autonomous prefectures in Hubei and Hunan provinces, relevant statistical data was not released in a timely manner, and such areas were excluded during writing; In response to the situation where some cities have missing values for certain years, based on the actual situation of the missing years, the average value of changes in values from adjacent years or linear interpolation methods are estimated

and supplemented before calculation. The descriptive statistics of the sample data are shown in Table 2.

Table 2. Descriptive Statistics of Sample Data

variable	Observation numbers	Mean value	mean value	minimum value	maximum value
Capital stock	880	7523.494	7583.375	170.09	53996.41
Number of employees in urban areas at the end of the year	880	47.04	38.45	7.796	380.4
Total electricity consumption	880	146.37	100.86	9.3408	737.68
Actual regional gross domestic product	880	1500.267	1348.8	286.7953	9750.604
Industrial wastewater discharge volume	880	4095.435	3285.87	60	20704
Industrial SO2 emissions	880	2.51	2.93	0.0192	14.1246
Industrial dust emissions	880	3.27	20.96	0.015	516.8812

Data source: The author collected and organized relevant data

4. Result Analysis

After using the SBM model with unexpected output to calculate the efficiency of green economic development in 80

prefecture level cities in the central region, the efficiency values of 80 prefecture level cities from 2012 to 2022 were obtained. The average values of each prefecture level city for 11 years were also calculated. Due to space limitations, this article selected the years 2012, 2017, 2022, and the average values to draw Table 3. Based on this, ArcGIS software was used to draw the selected data into Figure 1.

Table 3. Calculated Efficiency of Green Economy Development in the Central Region

city	He nan				city	An hui			
	2012	2017	2022	mean value		2012	2017	2022	mean value
Zheng zhou	0.6207	0.6621	1.0347	0.7369	He fei	0.6517	0.6908	0.9044	0.6978
Kai feng	0.6071	1.0211	1.0179	0.9565	Wu hu	0.6241	0.5944	0.6187	0.6065
Luo yang	0.6032	0.6551	0.7272	0.6335	Beng bu	0.5951	0.6426	0.6924	0.6378
Ping ding shan	0.5831	0.6020	0.6251	0.5967	Huai nan	0.5637	0.5576	0.5981	0.5673
An yang	0.5794	0.6042	0.6198	0.5945	Ma an shan	1.0009	0.5762	0.6005	0.6204
He bi	0.5761	0.5888	0.6303	0.5923	Huai bei	0.5587	0.5604	0.5864	0.5627
Xin xiang	0.5833	0.6966	0.6633	0.6068	Tong ling	0.5840	0.5707	0.5800	0.5675
Jiao zuo	0.5829	0.6090	0.6097	0.5932	An qing	0.6314	0.5931	0.6587	0.6120
Pu yang	0.5893	0.7337	0.6923	0.6609	Huang shan	0.6959	0.6057	0.7098	0.6507
Xu chang	0.6324	0.6423	0.8082	0.6618	Chu zhou	0.5996	0.6040	0.6995	0.6532
Luo he	0.6151	0.7177	1.1200	0.8229	Fu yang	1.0022	1.0006	0.6596	0.7181
San men xia	0.5771	0.6153	0.7125	0.6154	Su zhou	0.5981	0.6034	0.6296	0.6002
Nan yang	0.6121	0.6545	0.7233	0.6691	Lu an	0.6093	0.6519	0.6460	0.6326
Shang qiu	0.5854	0.6253	0.6691	0.6151	Bo zhou	0.6888	0.6263	0.7305	0.6506
Xin yang	0.6496	0.6609	1.1003	0.8213	Chi zhou	0.6542	0.6048	0.5979	0.5966
Zhou kou	0.6263	1.0392	1.0141	0.8371	Xuan cheng	0.5529	0.5935	0.6143	0.5865
Zhu ma dian	0.6535	0.7485	1.0216	0.7103					

Continued Table 3 Calculated Efficiency of Green Economic Development in the Central Region

city	Hu bei				city	Hu nan			
	2012	2017	2022	mean value		2012	2017	2022	mean value
Wu han	0.6925	1.0079	1.0619	0.9714	Chang sha	1.1772	1.0850	1.2061	1.1492
Huang shi	0.5832	0.5602	0.5983	0.5713	Zhu zhou	0.6562	0.6237	0.7447	0.6498
Shi yan	0.6094	0.7035	0.9803	0.7234	Xiang tan	0.5925	0.5869	0.6227	0.5920
Yi chang	0.6149	0.6106	1.0092	0.7599	Heng yang	0.7141	0.6093	0.6772	0.6289
Xiang yang	0.6470	0.6719	1.0375	0.7556	Shao yang	0.5983	0.6379	0.6591	0.6127
E zhou	0.5764	0.5684	1.0741	0.7018	Yue yang	0.7522	0.6153	0.8004	0.6748
Jing men	0.5843	0.6011	0.6569	0.5959	Chang de	1.0370	1.0038	1.0737	1.0498
Xiao gan	0.5788	0.6025	0.6417	0.5921	Zhang jia jie	1.0342	1.1964	1.0157	0.9923
Jing zhou	0.5728	0.5852	0.6508	0.5893	Yi yang	0.6105	0.6093	0.7046	0.6198
Huang gang	0.5932	0.6454	0.6769	0.6197	Chen zhou	0.5886	0.6045	0.6167	0.5942
Xian ning	0.5817	0.6018	0.6498	0.6652	Yong zhou	0.5886	0.6912	0.7126	0.6589
Sui zhou	0.6341	1.0471	1.0552	0.8513	Huai hua	0.6226	0.6195	0.6818	0.6157
					Lou di	1.0145	0.5880	0.5856	0.6211

Continued Table 3 Calculated Efficiency of Green Economic Development in the Central Region

city	Shan xi				city	Jiang xi			
	2012	2017	2022	mean value		2012	2017	2022	mean value
Tai yuan	0.7527	1.0441	1.0612	0.9232	Nan chang	0.6509	0.6362	0.7797	0.6558
Da tong	0.5539	0.5848	0.6664	0.5898	Jing de zhen	0.5720	0.5618	0.5993	0.5724
Yang quan	1.0164	1.0024	1.0697	0.8927	Ping xiang	0.5981	0.6015	0.6013	0.5890
Chang zhi	0.5797	0.5803	0.6935	0.5939	Jiu jiang	0.5577	0.5541	0.6052	0.5680
Jin cheng	0.5835	0.5813	1.0234	0.6666	Xin yu	1.0413	0.5861	0.6027	0.7437
Shuo zhou	0.6651	0.6141	1.0425	0.7978	Ying tan	0.6061	0.6151	0.7003	0.6163
Jin zhong	0.5748	0.6263	0.6857	0.6109	Gan zhou	0.5784	0.5723	0.6149	0.5799
Yun cheng	0.5703	0.5700	0.6098	0.5790	Ji an	0.5889	0.5635	0.6078	0.5754
Xin zhou	0.5448	0.6023	0.6475	0.5763	Yi chun	0.5688	0.5697	0.6226	0.5781
Lin fen	0.5796	0.5631	1.0078	0.6352	Fu zhou	0.5669	0.5857	0.6347	0.5822
Lv liang	1.0136	0.5906	0.7373	0.6458	Shang rao	0.5829	0.5657	0.5885	0.5746

Note: The data in this table was calculated by MaxDEA software and organized by the author.

Firstly, from the perspective of overall development, as shown in Figure 1 and Table 3, the efficiency of green economy development in the central region is generally at a low level and exhibits a clear spatial distribution imbalance. From the spatial distribution map of the average values in Figure 1, it can be seen that cities with high levels of green economy development efficiency are mostly concentrated in the central regions where research tends to focus, and there is a clustering effect. For example, the average green economy development efficiency of Changsha in 11 years is the highest in the study area, reaching 1.1492. In addition, Chang de and Zhang jia jie are 1.0498 and 0.9923, respectively, and Wuhan and Kaifeng are 0.9714 and 0.9565, respectively. We can find that these cities have a common feature, the tourism industry is relatively developed, and the tertiary industry associated with it accounts for a large proportion, so it has a small unexpected output and plays an important role in improving the efficiency of green economy development. The green economic development efficiency of prefecture level cities in the northern and eastern regions of the research area is at a low or relatively low level of development. Among them, the average green economic development efficiency of Huai bei is the lowest at 0.5627, Huai nan is 0.5673, Tong ling is 0.5675, and Jiu jiang is 0.5680. It can be found that these cities have a consciousness of developing green economy to improve the efficiency of green economic development in the context of national development of green economy. The eastern cities in the research area are adjacent to developed provinces in eastern China such as Zhejiang and Jiangsu, with a large population outflow and lagging economic development. The development of the tertiary industry is hindered, and they are in a passive position in terms of industrial optimization and upgrading. Cities such as Yun cheng and Da tong Jiao zuo and other cities, due to their location in northern China with harsh natural environments and being resource intensive cities, are also at a disadvantage in upgrading their industrial structure and improving the efficiency of green economic development. In addition, spatially speaking, compared with 2012 and 2017, the overall low level of green economy development in the central region has improved in 2022, especially with an increase in the number of cities with higher levels of green economy development efficiency. High level development efficiency cities are gradually spreading from the center to the

surrounding areas. It is more obvious that the green economy development efficiency of northern cities in the study area has improved significantly, rising one to two levels from the initial low level during the study period. However, on the other hand, the eastern region of the study area still shows a low level of development, indicating that there is still a lot of room for improvement in the efficiency of green economy development in the central region.

Secondly, we can see that the efficiency of green economic development in the vast majority of cities in the central region has significantly improved with the increase of years. Although there are still some cities with low levels of green economy development efficiency in the past 11 years, their green economy development efficiency has steadily improved. From Table 3, it can be seen that except for some cities, the green economy development efficiency of other cities in the past three years has gradually improved and the average is higher than that in 2012. The number of cities in the low-level range is also showing a decreasing trend, especially in the northern part of the study area. For example, Jin cheng increased from 0.5835 in 2012 to 1.0234 in 2022, Shuo zhou increased from 0.6651 in 2012 to 1.0425 in 2022, and Lin fen increased from 0.5796 in 2012 to 1.0078 in 2022. The number of efficiency level improvements in the development of green economy in central and western cities in the research area in 2022 has also significantly increased, indicating that the level of green economy development in the region's cities is better than in 2012. On the other hand, we can also see that the development efficiency of green economy in some cities has experienced a situation of breaking down and then improving. For example, Xin yu City has decreased from 1.0413 in 2012 to 0.6027 in 2022, and Ma a shan has decreased from 1.0009 in 2012 to 0.6005 in 2022. According to the theory of environmental Kuznets curve, it can be speculated that the reason for this phenomenon may be because at the beginning of the research period, the economic development level of these cities was relatively low, so the environmental pressure was relatively small, and the corresponding green economy development efficiency was relatively high. However, as the economy gradually develops, the environmental pressure begins to increase, and the corresponding unexpected output will increase. The efficiency of green economy development will decrease accordingly. However, the environmental pressure will decline after reaching a peak, this is also the reason why the efficiency of green economy development in these cities in 2022 has improved compared to 2017.

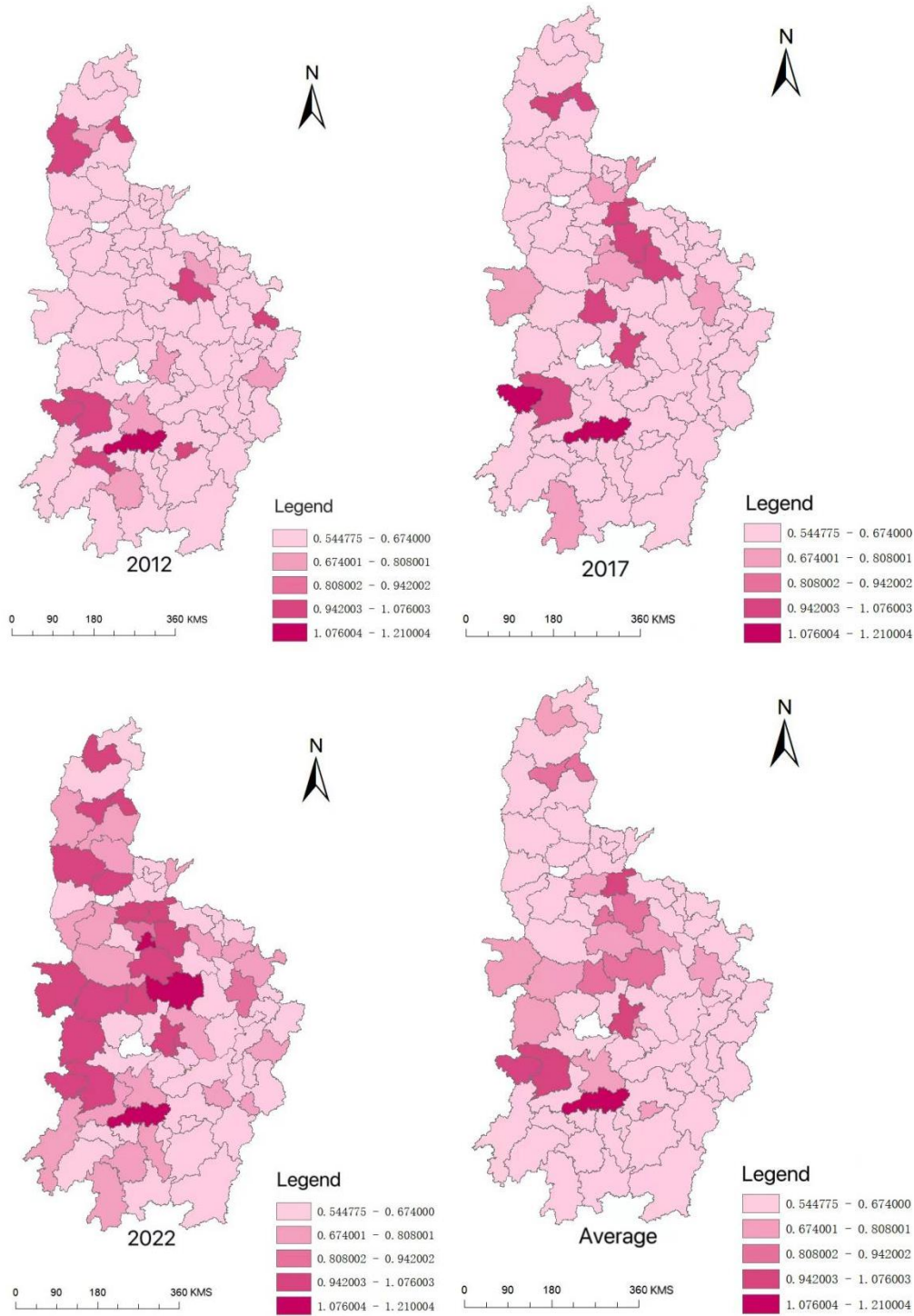


Figure 1. Efficiency of Green Economy Development in the Central Region

Note: Based on the calculated data, the author used the natural fracture method in ArcGIS 10.8 software to divide the study area into five parts: low level, low level, medium level, high level, and high level. The white part in the figure represents non research objects within the area.

5. Analysis of Factors Influencing the Efficiency of Green Economy Development

In order to further explore the factors that affect the efficiency of green economy development in central China, this article selected data from 80 prefecture level cities in the central region from 2012 to 2022 as samples and analyzed them using the Tobit model. The specific model is as follows:

$$GEE_{it} = \beta_0 + \beta_1 \ln PGDP_{it} + \beta_2 IND_{it} + \beta_3 TI_{it} + \beta_4 EDU_{it} + \beta_5 FIN_{it} + \beta_6 OPEN_{it} + \varepsilon_{it} \quad (6)$$

Among them, GEE represents the efficiency of green economy development; PGDP stands for Gross Domestic Product of an individual region; IND stands for Industrial Structure; TI stands for technology investment; EDU stands for Educational Investment; FIN stands for financial investment; OPEN represents the degree of openness to the outside world; i represent the i -th city; T represents the year; β_i is the coefficient of each indicator; ε it is a random error.

5.1. Variable Declaration

Green Economy Development Efficiency (GEE). This article uses the calculated super efficiency SBM index in the central region, which includes unexpected outputs, as the explanatory variable.

Economic Development Level (PGDP). The efficiency of green economy development is closely related to the level of economic development in a region. In academic research, the per capita GDP is often used to measure the level of economic development in a region. This article takes the per capita GDP in 2012 as the base year and calculates it using the deflator index to obtain the per capita GDP. In order to make the data more stable, the logarithm of the calculated per capita GDP is taken.

Industrial Structure (IND). The changes in industrial structure usually affect the allocation and utilization of resources. This article selects the ratio of the proportion of the tertiary industry to the proportion of the secondary industry in the regional gross domestic product to represent the state of industrial structure.

Technology investment (TI). Technological innovation can improve the efficiency of resource utilization and thus play a role in the development efficiency of green economy. Therefore, this article selects the proportion of government technology investment to fiscal expenditure to represent the level of technology investment.

Educational investment (EDU). Education provides intellectual and human support for economic development by improving the overall cultural quality of society. This article uses the proportion of education expenditure to fiscal expenditure to represent education investment.

Financial support (FIN). The investment of financial resources can reasonably guide the allocation and transfer of social resources, thereby affecting the efficiency of economic development. This article uses the ratio of year-end loan balance to year-end deposit balance to represent skill support.

The level of openness to the outside world (OPEN). This article selects the proportion of a city's total import and export volume to its regional gross domestic product in the current year to represent its level of openness to the outside world.

5.2. Data Description

This article takes 80 prefecture level cities in the central region as the research object, selects data from 2012 to 2022 for empirical analysis, and the data comes from the "China Urban Statistical Yearbook", "Statistical Yearbook" of each prefecture level city, and statistical bulletins of each prefecture level city.

5.3. Empirical Analysis

Based on the above calculation methods and indicator selection, this article conducted Tobit regression analysis on the relevant data using Stata17 software. The specific regression results are shown in Table 4:

Table 4. Regression Results of Factors Influencing the Efficiency of Green Economy Development in the Central Region

Variable	Coefficient	Std. err.	z	Prob.
C	-1.039067	0.2693387	-3.86	0.000***
lnPGDP	0.16667364	0.0250088	6.67	0.000***
IND	0.0424809	0.0145971	2.91	0.004***
TI	0.4947874	0.3648125	1.36	0.175
EDU	-0.4879792	0.1991859	-2.45	0.014**
FIN	0.0522509	0.0148735	3.51	0.000***
OPEN	-0.182014	0.1063351	-1.71	0.087*

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

From the above table, it can be concluded that:

The per capita regional GDP has a significant positive impact on the efficiency of green economic development, with an impact coefficient of 0.16667364, indicating that for every 1% increase in per capita regional GDP, the efficiency of urban green economic development increases by 0.16667364%. This is because with the development of the economy and the continuous increase in per capita regional GDP, people are gradually pursuing environmental quality, which has a significant impact on the efficiency of green economy development.

The industrial structure has a significant positive impact on the efficiency of green economic development, with an impact coefficient of 0.0424809, indicating that for every unit increase in industrial structure, the efficiency of green economic development will increase by 0.0424809 units. The increase in the proportion of the tertiary industry will inevitably reduce the development of the secondary industry. The emission of pollutants from the secondary industry is an important factor affecting the development of green economy. The decrease in the proportion of the secondary industry and the reduction in pollutant emissions have led to an improvement in the efficiency of green economy development.

The coefficient of technology investment is 0.4947874, which has a positive impact on the efficiency of green economic development, but its P-value is 0.175, which is not significant at a 10% confidence level. This may be because the current economic development stage in the central region is relatively low, and the industry is in the labor-intensive processing industry. The results of a large amount of technology input and output cannot immediately take effect at the current stage, resulting in a lag effect.

Education investment has a significant negative impact on the efficiency of green economic development, with an impact coefficient of -0.4879792, indicating that for every unit increase in education investment, the efficiency of green economic development will decrease by 0.4879792 units. This may be because the structure of education expenditure may be unreasonable, with redundant or other unreasonable aspects of education investment, thus having a negative impact on the efficiency of green economy development.

Financial support has a significant positive impact on the efficiency of green economy development, with an impact coefficient of 0.0522509, indicating that for every 1 unit increase in financial support, the efficiency of green economy development will increase by 0.0522509 units. Financial development can reasonably regulate resources, and evaluating the efficiency of green economic development in a region is a factor. Financial support can provide relevant enterprise funds for upgrading and transformation, while

improving production efficiency and energy conservation and emission reduction.

The level of opening up to the outside world has a significant negative impact on the efficiency of green economic development. The impact coefficient is -0.182014. Indicating that for every 1 unit increase in the level of opening up to the outside world, the efficiency of green economic development will decrease by 0.182014 units. Perhaps because the labor force in the central region is its natural resource, during the process of opening up to the outside world, it mainly undertakes high energy consuming and labor-intensive industries transferred from foreign or eastern regions. Undertaking such industries is not conducive to improving the efficiency of green economy development.

6. Suggestion and Countermeasure

(1) Accelerate the adjustment of industrial structure

The central region has abundant labor resources and indeed has advantages in undertaking the transfer of the secondary industry. However, in the long run, the development of the industry will ultimately shift towards the tertiary industry. It is necessary to actively guide the optimization and upgrading of the secondary industry in the central region, develop the tertiary industry, and increase its proportion. For the current stage of the secondary industry in the region, it is necessary to strengthen guidance, guide it to improve its processes, and eliminate high energy consuming enterprises and processes.

(2) Reasonably plan education expenditures

Overall, the education resources in the central region are relatively weak, with a small number of universities and research institutes, and insufficient cultivation of outstanding talents. Education has a negative impact on the efficiency of green economy development, with more investment in basic education leading to relatively less investment in higher education. The greatest improvement in the efficiency of green economy development is in talent cultivation in higher education. Therefore, it is necessary to actively adjust the structure of education investment, appropriately tilt towards higher education investment, improve the development level of higher education, cultivate outstanding talents, and let talents have a reverse effect on the development of green economy.

(3) Deepen opening-up to the outside world

With the deepening of China's opening-up to the outside world, provinces in the central region should also build a multi-level and all-round opening-up pattern in accordance with relevant national policies. In foreign trade, they should strengthen the exchange and introduction of high-tech industries, avoid accepting high energy consuming and high polluting industries transferred from abroad as much as possible, actively utilize foreign investment to adjust industrial structure and develop green industries, and promote the steady improvement of green economic efficiency.

Acknowledgment

Supported by Graduate Student Innovation Program of Chongqing University of Technology (Grant No. gzlcx20243483)

References

[1] Li Xuhui, Wang Jingwei, Wu Quan, etc Differences and Causes of Industrial Green Development in China's Five Key

Regions under the "Dual Carbon" Goal [J]. *Economic geography*, 2023, 43(08):103-112.

- [2] Shi Yufang, Lan Xinyi. Spatial Network Structure Study on Green Development Efficiency of Resource based Cities in Central China [J]. *Forum on Statistics and Information*, 2021, 36 (10): 86-98.
- [3] Zheng Hongxia, Wang Yi, Huang Baorong. A review of research on green development evaluation index system [J]. *Industrial Technology and Economics*, 2013, 33 (02): 142-152.
- [4] Zhou Huirong, Yang Jianzhou. Analysis of Factors Influencing China's Green Demand [J]. *Journal of Fujian Agriculture and Forestry University (Philosophy and Social Sciences Edition)*, 2006 (01): 55-57.
- [5] Liu Xiu. The Impact and Mechanism of Smart Logistics on Regional Green Economy Development: An Empirical Study Based on the Yangtze River Economic Belt [J]. *Business Economics Research*, 2023 (22): 97-100.
- [6] Wang Hongyi, Xie Dongshui. Distorted Land Supply Structure and Green Economic Efficiency: An Empirical Study Based on Chinese Urban Panel Data [J]. *Statistics and Decision making*, 2023, 39 (19): 126-131.
- [7] He Jing, Li Zhanjiang, Su Jinmei. Construction of Green Economy Evaluation Index System Based on R-Cluster Grey Relational Advantage Analysis [J]. *Science and Technology Management Research*, 2018, 38 (10): 90-98.
- [8] Xue Long. Construction of Measurement System for Green Economy Development [J]. *Statistics and Decision making*, 2012 (18): 21-24.
- [9] Zhang Wang, Zhou Yueyun, Xie Shixiong. Analysis of the Pattern and Differences of Low carbon and Green Development in Chinese Cities: A Case Study of the Top 110 Cities with GDP Values at the Prefecture Level and Above. *World Geographic Research*, 2013, 22 (04): 134-142+73.
- [10] Zeng Xiangang, Bi Ruiheng. Overall Evaluation and Regional Differences Analysis of Green Economy Development [J]. *Environmental Science Research*, 2014, 27 (12): 1564-1570
- [11] Zhang Haixia, Lin Tongzhi. Impact of Digital Economy Development on Green Economy Performance and Spatial Correlation Analysis [J]. *Business Economics Research*, 2023 (16): 112-115.
- [12] Chen Yang, Shi Jiajing, Gao Wenqun et al. A Study on the Dynamic Evolution and Differentiation of Development Efficiency of China's Green Economy [J]. *Statistics and Decision making*, 2023, 39 (11): 94-99.
- [13] Kong Lingzhang, Li Jinye. The Impact of Digital Economy Development on China's Green Economy Efficiency [J]. *Economic System Reform*, 2022 (06): 67-73.
- [14] Xu Yijing, Dai Yuhui. The Impact of Circulation Industry Agglomeration on the Development of Green Economy: Exploration of Implementation Mechanism and Heterogeneity [J]. *Business Economics Research*, 2023 (10): 37-40.
- [15] Wu Xuxiao. Research on the Evolution of Regional Green Economy Efficiency and Its Influencing Factors [J]. *Business Research*, 2014 (09): 27-33.
- [16] Liu Haoran. Measurement and influencing factors of green economic efficiency in the Beijing Tianjin Hebei region: analysis based on super efficiency SBM and Tobit models [J]. *Ecological Economy*, 2023, 39 (04): 67-73.
- [17] Zhang Jun, Wu Guiying, Zhang Jipeng. Estimation of inter provincial material capital stock in China: 1952-2000 [J]. *Economic Research*, 2004 (10): 35-44.