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Original Research

Research on the Impact of Environmental Regulation on the Regional Green Economy Efficiency of China Based on Super-Efficiency DEA-Tobit Model

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Abstract

This paper estimates the green economy efficiency of 30 provinces (autonomous regions and municipalities) in China from 2008 to 2020 based on the super-efficiency DEA model. On this basis, the Tobit model is used to study the impact of environmental regulations on green economy efficiency. The results show that (1) from the perspective of spatial distribution; the average value of the national green economy efficiency during 2008-2020 is about 0.75. The green economy efficiency level in the eastern region is significantly higher than the national average level, and the green economy efficiency index in the central region is second only to the eastern region. Western regions except Shaanxi have green economy efficiency index less than 1. From the perspective of time series changes, it can be roughly seen that during the period from 2008 to 2020, the green economic efficiency of all regions has been showing a slow upward trend; (2) The impact of environmental regulations on the efficiency of the national green economy has a restraining effect. At the 5% significance level, the coefficient of environmental regulation on the green economic efficiency of the eastern region is significantly positive, and the coefficient of environmental regulation on the green economic efficiency of the central and western regions is significantly negative; (3) Regional economic development has a significant impact on the green economy efficiency of other regions except for the eastern region; foreign direct investment has a negative impact on all regions; the impact of fiscal decentralization on the central and western regions is negative, and the impact on the country and the east is positive; Investment in fixed assets is not significant to the western region, and other regions are significantly positive;

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the industrial structure is not significant to the eastern and western regions, and has a significant impact on the country and the central region.

Keywords: super-efficiency DEA, environmental regulation, green economic efficiency

Introduction

The process of industrialization has greatly enhanced China's comprehensive economic strength, but under the dual constraints of resources and the environment, green development has become the trend of the new era. The Fifth Plenary Session of the 18^{th} Central Committee put forward five development concepts: innovation, coordination, green, openness, and sharing. Among them, green is a necessary condition for sustainable development. At the same time, the Communiqué of the Fifth Plenary Session of the Eighteenth Central Committee clearly stated the idea of adhering to green development. The "Thirteenth Five-Year Plan" released in 2016 also embodies the concept of green development in all fields and links involved in development. The traditional economic growth mode of high input and low output, high consumption and low income, high speed and low quality is no longer suitable for China's high-quality development mode [1]. Green development has become imperative development ideas and development methods under the background of the "new normal". The concept of green development is developed on the basis of the idea of "sustainable development". It is a new development model with the core of correctly handling the relationship between economic development and environmental protection. Among them, the term "green economic efficiency", which has evolved from the concept of "green development" and is highly representative, has increasingly become a hot topic for scholars [2-4]. Green economic efficiency is the effective quantification of the quality of green economic development, which is to evaluate and measure regional economic development under the premise of economic growth and environmental protection [5]. The purpose of green economy efficiency is to measure the efficiency of economic operation, which can be regarded as the integration of green economy and economic efficiency. Compared with traditional total factor productivity, green economy efficiency considers the impact of resources and the environment on production efficiency, considers resource factors in production inputs, and treats environmentally harmful parts as undesired outputs in the output, aiming to be more comprehensive, objectively evaluate the efficiency of economic operation.

In order to effectively balance the relationship between economic development and environmental protection, the 19th National Congress of the Communist Party of China put forward the task of "implementing new development concepts and building a modern economic system." The modern economic system requires green development, and regional industrial transfer plays an important role in coordinating economic development and environmental protection, and promoting green development. In the context of increasingly prominent environmental problems, environmental regulations have become an important way to control environmental pollution and improve the efficiency of green economy. Environmental regulation is an exogenous market failure correction tool, which brings external incentives to the technological innovation of enterprises and the transformation and upgrading of industries. How to make good use of potential development opportunities in the new era, design an effective and reasonable environmental regulatory system to achieve resource-saving and environmentally friendly economic sustainable development, whether the implementation of environmental regulations can effectively improve China's environmental quality, environmental regulatory policy tools are different What are the differences in the efficiency of regional green economy? This research attempts to expand from the following aspects: first, use the super-efficiency DEA model to measure the green economy efficiency considering undesired output, and analyze the spatial distribution differences of green economy efficiency from the overall and different regional perspectives; second, use the Tobit model to empirically study the relationship between environment regulation and green economy efficiency, on the basis of empirical analysis, attempts to explore countermeasures to improve the efficiency of green economy from the perspective of environmental regulation, and at the same time provide a basis for formulating appropriate intensity environmental regulation policies in different regions.

Literature Review

Measurement of Green Economy Efficiency

Traditional economic efficiency refers to total factor productivity. Scholars mainly use the Solow Residual Value Method SFA (Stochastic Frontier Method) and DEA (Data Envelopment Analysis) methods to measure total factor productivity. The DEA method is a non-parametric deterministic production frontier method, which measures the technical efficiency of the production unit. The DEA method is widely used because it can handle multiple inputs and multiple outputs. Early use of the DEA method to measure total factor productivity include Lin and Liu (2003) [6], Deng and Yu (2006) [7], etc., but there are problems It does not consider the impact of environmental factors on output.

In recent years, the DEA method has experienced development from the shallower to the deeper. The idea of evaluating efficiency in the initial DEA model is to use the least input to produce the most output. But in actual production activities, by-products such as environmental pollution are also included in the output, so producing as much output as possible means more pollution will be produced, and by-products such as pollution must be reduced to achieve the purpose of economic efficiency. Therefore, the initial DEA method is inconsistent with the original intention of the efficiency evaluation. Lin (2003) pointed out that due to the lack of market pricing for environmental pollution or environmental policies related to pollution taxes; it is difficult to include environmental pollution in production costs [8]. Fare and Pasurka (1989) proposed to use the hyperbolic nonlinear programming method to deal with, that is, to reduce the undesired output, the expected output must be reduced [9]. Chambers et al. (1996) [10] and Chung et al. (1995) [11] proposed that pollution should be an undesired output with negative externalities, at this time, the restrictive effect of environmental pollution on economic development is the first was discovered again. Since then, Färe et al. (2001) [12], Boyd et al. (2002) [13] have applied pollution as an undesired output in their articles.

Since then, many researchers have proposed different methods to deal with undesired output, such as Zhu (2003) [14] and Scheel et al. (2001) [15] "reciprocal transformation method", Seiford and Zhu (2002) [16] "conversion vector method" and the directional distance function of Färe et al. (2003). Since then, the most widely used empirical research is the SBM-DEA model proposed by Tone (2001,2002) [17-18]. The Super SBM model is based on the modified slack variable, so that the efficiency value of the decision-making unit is not restricted by the [0,1] interval, and can well evaluate the efficiency and ranking of those decision-making units with an efficiency value of 1. Since then, this method has been widely used by scholars at home and abroad. Li et al. (2013) proposed the Super SBM-DEA model that considers undesired output [19]. Hu et al. (2020) used the SBM-Undesirable and Malmquist-Luenberger models to establish an input-output indicator system based on the concept of green development to evaluate the static efficiency and dynamics of 20 resource-based cities in the arid area of northern China from 2006 to 2016[20]. Lozano and Gutiérrez (2011) also concluded that the SBM method is more discerning than the directional distance function method. Many scholars in China have also calculated total factor productivity considering environmental pollution [21]. Sun and Zhu (2019) based on the data of the key provinces of the "Belt and Road" from 2006 to 2016, using the SBM model and the Malmquist index to analyze the efficiency of the green economy and total factor productivity, based on this analysis of the provinces and regions as a whole Scientific evaluation of the development level of the green economy [22]. Zhou et al. (2020) used the super-efficiency SBM model and the Tobit model to study the influencing factors [23]. Lv (2020) used DEA model to measure the green economic efficiency of various cities in Guangdong Province from 2011 to 2018 [24]. Ren and Wang (2018) using non-angle SBM model to measure the green economy efficiency value of Chinese provinces from 2011 to 2015 [25].

Impact of Environmental Regulations on the Efficiency of Green Economy

Kolstad and Xing (2002) studied industries with stricter environmental regulations in the United States and found that the cost of compliance with environmental regulations is greater than the economic growth effect, leading to green total factor productivity declines [26]. Some scholars have found that the economic growth effect is less than the environmental cost effect, and the green total factor will decline (Berman and Bui 1990 [27]). Qian (2015) [28] found that environmental regulations have a U-shaped curve relationship that first restrains and then promotes green economy efficiency in eastern China. Yuan and Xie (2016) based on research on China's inter-provincial panel data and found that there is a U-shaped curve relationship between environmental regulations and the green productivity of industrial enterprises [29]. Shen et al. (2017) confirmed that the impact of command-and-control environmental regulations on it is shown as a "U"-shaped relationship [30]. Liu et al. (2016) found that there is an inverted U-shaped curve relationship between market-based environmental regulations and green economic efficiency [31]. Qi and Wang (2016) found that there is an inverted "U"-shaped relationship between environmental regulations and green economic efficiency [32]. Zhang et al. (2018) found that environmental regulations have an inverted "U" that promotes and then weakens green economic efficiency [33]. Zhang et al. (2016) empirically analyzed different types of environmental regulations, the effect of influencing technological innovation will be different, and environmental governance control can support production efficiency [34]. Luo and Chen (2018) found that there was an obvious threshold effect between environmental regulation and green innovation efficiency [35]. Gong and Zhang (2020) found that the intensity of China's environmental regulations and the efficiency of green economy from 2006 to 2017 have shown an overall upward trend [36]; Zhang and Fan (2020) found that different types of environmental regulations have different impacts on the efficiency of green economy, from high to low in order of administrative type, market type and public participation type [37]; Huang and Pomegranate (2020) found that the overall efficiency of the green economy in the western region fluctuates, there are obvious differences in the development of green economy among provinces; environmental regulations have a significant inhibitory effect on the efficiency of regional green economy [38]; Wang and Sun (2020) found that the impact of green economic efficiency in the eastern, central and western regions of the sample presents different characteristics [39].

To sum up, due to the different research methods, the research results of environmental regulation and economic efficiency also have inconsistent conclusions such as promotion, inhibition or uncertainty. The previous literature mostly used linear models to estimate the impact of environmental regulations on economic efficiency, and the conclusions reached also support strengthening the intensity of environmental regulations. But it is worth thinking about whether the greater the intensity of environmental regulations, the higher the efficiency of the green economy? There are differences in resource endowments, economic development levels, and industrial structures in various regions in China, and there may be differences between environmental regulations and green economic efficiency. Relationship, it is necessary to analyze the spatial difference and distribution of regional green economic efficiency. At the same time, there is still insufficient literature on the impact of environmental regulations on the efficiency of green economy in different regions, and there is room for further expansion.

Methods

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (Data Envelopment Analysis, abbreviated as DEA) is developed by Charnes et al. (1978) [40] proposed a calculation model used to evaluate the relative effectiveness of the same departments. Among them, compared with the more traditional CCR model and BCC model, but in the efficiency measurement, the traditional DEA model often encounters a situation where many decision-making units are 1 at the same time, which greatly limits the decision-making units with the same efficiency as 1. Therefore, Tone (2002) [18] proposed the Super SBM-DEA model, and Li et al. (2013) [19] proposed the Super SBM-DEA model to deal with undesired output. The advantage of this model is that the efficiency value is not restricted by the [0,1] interval, and it can evaluate the efficiency and ranking of decision-making units whose efficiency values are all 1. Moreover, the super-efficiency model can effectively deal with undesired output through the data conversion function. Therefore, this paper adopts the super-efficiency DEA model proposed by Tone to measure the green economic efficiency of various regions in China. The mathematical model is as follows:

$$\begin{cases} min\left[\theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_i^+\right)\right] \\ s.t. \sum_{n} X_{ij}\lambda_j + s_i^- \leq \theta X_0 \\ \sum_{n} Y_j\lambda_j - s_r^+ = Y_0 \\ \lambda_j \geq 0, j = 1,2,\cdots,n, s_i^- \geq 0, s_r^+ \geq 0 \end{cases}$$

In the formula: s_r^+ and s_i^- are slack variables, which represent input excess and output deficit respectively; λ_j represents the calculated weight coefficient; ε is the non-Archimedean infinitesimal.

Tobit Model

Because the dependent variable at the end of its range, that is, in some cases, the value range of the explained variable may be restricted which is called restricted explained variable. Since the green innovation efficiency values measured in this paper are all greater than 0, It is in a restricted range, so this study should adopt the Tobit model for analysis. Tobit model is an econometric model proposed by economist Tobin (1958) [41] when studying the demand for consumer durables. The typical feature of the Tobit model is that the explanatory variable X_i is observable, while the resolved variable Y can only be observed in a restricted way, that is, the value of Y is restricted to a certain range, and the observed value is truncated.

Regarding the issue of regional green economy efficiency, it is necessary to analyze the efficiency of the green economy itself, but also to conduct in-depth research on its influencing factors. Therefore, this study will use the Tobit model to analyze the factors that affect the efficiency of the regional green economy, and provide sufficient empirical data for subsequent policy recommendations. The build model is as follows:

$$y_{it} = \begin{cases} \alpha_{it} + \beta^T x_{it} + \varepsilon_{it}, y_{it} \geq 0 \\ 0 \quad , y_{it} < 0 \end{cases}$$

Among them, the explained variable y_{it} is the green economy efficiency of the i-th region in year t. x_{it} is an explanatory variable, β^T is an unknown parameter, $\varepsilon_{it} \sim N(0, \sigma^2)$. This model is a cut regression model of panel data, the explanatory variable x_{it} takes the actual observation value, and the explanatory variable y_{it} is in a restricted manner Value: When $y_{it} \geq 0$, the actual observation value is taken; when $y_{it} < 0$, the observation value is cut to 0. α_{it} is the fixed effect of area i in year t, which is an unknown certain constant.

Results

Results of Calculation of Regional Green Economy Efficiency

Construction of Measurement Index System

Green economic efficiency is an economic efficiency indicator that emphasizes the unity of social economic benefits and ecological environmental benefits. It not only measures the utilization efficiency of input elements in the production process, that is, the ability to obtain the desired output, but also measures the same time in the economic process. The undesired output produced is the resource and environmental cost paid while obtaining the expected output. Based on the meaning of green economic efficiency and model data requirements, this paper constructs the input and output indicator system needed to measure the efficiency of green economy (Table 1). Among them, because the capital stock of each province (or autonomous region or municipality directly under the Central Government) cannot be directly obtained in the statistical yearbook, this paper draws on the method proposed by Pittman et al. (1983) [42] and uses the perpetual inventory method to calculate the capital stock: Kt = (1 – δ) Kt – 1 + It, where Kt is the capital stock in period t; It is the investment in period t, replaced by total fixed capital investment; Kt-1 is the capital stock in period t-1; δ is the depreciation rate of capital; initial capital stock. The calculation of the depreciation rate and the calculation of the depreciation rate all refer to Shan (2008) [43].

Results of China's Regional Green Economy Efficiency Measurement

This paper uses DEAP2.1 software, and the calculation results are shown in Table 2.

From the perspective of spatial distribution, the average value of the national green economy efficiency from 2008 to 2020 is 0.75, and the green economy efficiency level in the eastern region is significantly higher than the national average level, especially in places like Beijing, Tianjin, Shanghai, and Jiangsu. The higher efficiency indicates that the negative effect of environmental pollution is less than the positive economic increase effect, and the green economy efficiency index in the eastern region is mostly greater than 0.8, which indicates that the green economy efficiency of most provinces in the eastern region has increased, and the regional production level of these provinces is higher and less environmental pollution. The green economy effciency indexes of the western region are all less than 1. For example, the green economy efficiency of Guizhou, Gansu, and Ningxia is low, which is related to the lower expected output, mainly environmental pollution Bringing larger costs in exchange for smaller economic benefits; indicating that these provinces have problems with insufficient regional production, serious environmental pollution, or large resource depletion. From the perspective of time series changes, it can be roughly seen that during the period from 2008 to 2020, whether it is in the eastern region or the central and western regions, the efficiency of the green economy has been showing a slow upward trend. In general, the efficiency of China's green economy has continued to increase.

This phenomenon is caused by a combination of many factors. On the one hand, compared with the central and western regions, the eastern region is in excellent development. The geographical advantage of the higher openness and the coastal area has resulted in higher human capital, high-level infrastructure, and advanced The economic model and externally excellent emission reduction machinery and equipment create good conditions for the efficiency of the green economy; On the other hand, the central and western governments are aiming at economic development, but lack strict implementation of environmental and ecological policies. The economy must be improved, and the law must be allowed. This has opened the green light for various economic developments and for enterprises. The central and western regions are relatively backward in education, economic development, openness to the outside world, and marketization. Enterprises with serious coastal pollution have also moved to the west, which further hinders the coordinated development of the environment and the economy.

Table 1. Green economy efficiency measurement index system.

Indicators	Types of indicators	Indicators composition
Input indicators	Labor input	Number of employed population by region
	Capital input	Capital stock
	Energy input	Total energy consumption
Output indicators	Expected output	GDP
	Undesired output	Industrial waste gas emissions
		Total industrial wastewater discharge
		Industrial solid waste discharge

Table 2. China's regional green economy efficiency measurement results.

	Province or cities with provincial status	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Eastern	Beijing	2.632	2.641	2.655	2.732	2.752	2.802	2.845	2.894	2.945	3.064	3.157	3.227	3.378	2.902
	Tianjin	0.711	0.715	0.727	0.737	0.766	0.772	0.785	0.809	0.823	0.846	0.851	0.894	0.947	0.799
	Hebei	0.334	0.342	0.351	0.367	0.378	0.389	0.407	0.468	0.498	0.546	0.587	0.598	0.665	0.456
	Liaoning	0.367	0.376	0.389	0.392	0.396	0.407	0.412	0.416	0.421	0.427	0.432	0.441	0.455	0.410
	Shanghai	2.345	2.354	2.612	2.721	2.735	2.746	2.776	2.788	2.811	2.845	2.884	2.933	2.967	2.732
	Jiangsu	0.876	0.888	0.894	0.899	0.915	0.925	0.937	0.955	0.979	0.997	1.016	1.248	1.399	0.994
	Zhejiang	0.867	0.869	0.876	0.885	0.893	0.901	0.917	0.936	0.944	0.968	0.975	0.984	0.999	0.924
	Fujian	0.701	0.717	0.738	0.748	0.759	0.769	0.772	0.789	0.793	0.796	0.806	0.817	0.834	0.772
	Shandong	0.467	0.477	0.488	0.496	0.502	0.521	0.534	0.547	0.557	0.571	0.582	0.587	0.592	0.532
	Guangdong	0.784	0.791	0.798	0.816	0.825	0.845	0.858	0.869	0.887	0.901	0.923	0.935	0.947	0.860
	Hainan	0.801	0.813	0.825	0.836	0.848	0.859	0.872	0.883	0.896	0.904	0.923	0.936	0.966	0.874
Central	Shanxi	0.413	0.416	0.424	0.427	0.435	0.445	0.451	0.458	0.464	0.473	0.481	0.492	0.495	0.452
	Jilin	0.511	0.514	0.516	0.518	0.525	0.528	0.536	0.546	0.556	0.568	0.576	0.583	0.589	0.544
	Heilongjiang	0.576	0.581	0.584	0.596	0.603	0.614	0.625	0.633	0.641	0.644	0.657	0.634	0.668	0.620
	Anhui	0.702	0.715	0.729	0.731	0.734	0.741	0.756	0.776	0.781	0.797	0.809	0.813	0.827	0.762
	Jiangxi	0.804	0.813	0.835	0.838	0.841	0.844	0.849	0.854	0.856	0.858	0.866	0.867	0.871	0.846
	Henan	0.512	0.513	0.515	0.571	0.523	0.533	0.537	0.558	0.562	0.576	0.588	0.599	0.633	0.555
	Hubei	0.485	0.491	0.505	0.519	0.527	0.538	0.545	0.549	0.557	0.568	0.575	0.579	0.582	0.540
	Hunan	0.627	0.636	0.642	0.657	0.678	0.691	0.706	0.712	0.726	0.738	0.748	0.755	0.762	0.698
Western	Neimenggu	0.611	0.614	0.625	0.627	0.628	0.636	0.642	0.651	0.654	0.654	0.657	0.666	0.671	0.641
	Guangxi	0.623	0.625	0.633	0.641	0.652	0.655	0.661	0.672	0.681	0.685	0.693	0.711	0.725	0.666
	Chongqing	0.512	0.516	0.518	0.523	0.529	0.533	0.538	0.545	0.557	0.568	0.575	0.588	0.596	0.546
	Sichuan	0.518	0.525	0.529	0.531	0.545	0.552	0.556	0.571	0.583	0.593	0.604	0.617	0.627	0.565
	Guizhou	0.315	0.313	0.317	0.322	0.329	0.331	0.332	0.335	0.341	0.345	0.349	0.354	0.369	0.335
	Yunnan	0.504	0.507	0.513	0.517	0.522	0.525	0.509	0.517	0.521	0.526	0.534	0.538	0.549	0.522
	Shaanxi	0.515	0.518	0.523	0.533	0.537	0.539	0.542	0.545	0.552	0.557	0.567	0.578	0.589	0.546
	Gansu	0.217	0.219	0.249	0.271	0.289	0.296	0.317	0.332	0.346	0.378	0.386	0.399	0.414	0.316
	Qinghai	0.373	0.376	0.381	0.388	0.376	0.378	0.389	0.392	0.392	0.393	0.399	0.407	0.424	0.390
	Ningxia	0.246	0.266	0.279	0.281	0.284	0.289	0.291	0.296	0.297	0.299	0.305	0.314	0.321	0.290
	Xinjiang	0.366	0.371	0.378	0.379	0.385	0.389	0.396	0.396	0.406	0.414	0.419	0.428	0.436	0.397
National mean		0.677	0.684	0.702	0.717	0.724	0.733	0.743	0.756	0.768	0.783	0.797	0.817	0.843	0.750

The Impact of Environmental Regulations on Regional Economic Efficiency

The Theoretical Mechanism of the Impact of Environmental Regulation on the Efficiency of Regional Green Economy

The impact of environmental regulations on manufacturers is divided into direct impact and indirect impact mechanisms. Environmental regulatory tools affect the efficiency of the green economy through these two mechanisms, but some of these two mechanisms will have a negative impact on economic efficiency, and some will have a positive impact. Ultimately, the combined effect of these impacts determines the net effect of green economic efficiency.

Direct transmission mechanism: From a cost perspective, the most direct impact of environmental regulations is to increase the cost of pollution control for enterprises. Whether it is buying clean production equipment or paying pollution taxes and fees, these increase the pollution treatment investment of enterprises and lead to higher enterprise costs. In addition, environmental regulations may also lead to a decline in product demand. If the prices of the products produced by the enterprise or the key inputs required for the production of products are imposed high taxes and fees after the implementation of environmental regulations, it will directly lead to a decline in product demand. In addition, pollution monitoring and reporting caused by environmental regulations can easily increase the transaction and decision-making costs of enterprises. From a benefit point of view, environmental regulations have increased the demand for pollution monitoring equipment and cleaner production equipment, which will cause an increase in corporate investment. The potential benefits generated by environmental regulations will increase the profit level of enterprises, thereby motivating enterprises to increase investment in research and development, encouraging technological innovation, and thus improving the production efficiency and profits of enterprises. In addition, for companies that have already used clean equipment or have already invested in pollution control, environmental regulations will cause the cost of their competitors to rise, thereby improving the company's relative competitiveness in the industry.

Indirect transmission mechanism: From a cost point of view, higher environmental quality requirements will increase the operating costs of inputs such as raw materials, labor, and energy. For example, the trading activities of pollutant emission permits increase the transaction costs of enterprises, and pollution monitoring, measurement and Reporting and other activities have increased the operation and decision-making costs of the enterprise. In addition, the pollution control expenditure of enterprises will produce a "crowding effect", that is, because the amount of investment of enterprises in a period of time is fixed, increasing the pollution control expenditure of enterprises will inevitably reduce other productive investments, resulting in a decline in enterprise output and the economic benefits of declining. From the perspective of benefits, the effects of environmental regulations on the economy can be divided into three aspects. First, improve the efficiency of resource use. Porter believes that pollution is a manifestation of inefficient use of resources. With the improvement of environmental regulations and the reduction of environmental pollution, the utilization rate of resources also rises. Second, create new business opportunities. The improvement of environmental regulations forces companies to produce more "green" products, and green products can usually claim higher surplus value to increase corporate income. It can increase consumers' trust in the company, and it can also improve the company's brand. Well-known, but also can enter the country that implements strict environmental standards. Third, reduce corporate risks. The better environmental quality achieved by environmental regulations can allow companies to face a smaller risk of accidents and legal sanctions. The relationship between environmental protection companies and the local government will be more harmonious, thereby reducing the costs of related taxes, fines, and litigation fees. A good image of an environmentally friendly company is also conducive to establishing a good relationship between the company and local residents, and is conducive to brand expansion and company development.

From the above analysis, it is not difficult to see that the impact mechanisms of environmental regulations on economic growth are complex. These mechanisms not only have a positive or negative impact on the economy, but for specific enterprises, not all mechanisms work at the same time. These mechanisms are not only differentiated by region, but also by industry. Different regions have different mechanisms for exerting effects and produce different net effects; different industries have different mechanisms for exerting effects, and the net effects produced are also different. These net effects will lead to differences in productivity, profitability, technological innovation, and competitiveness. Faced with such a complicated mechanism of play, this article will mainly construct an econometric model from the perspective of my country's provincial panel for empirical analysis.

Index Selection and Model Construction

(1) Explained variables.

Based on the results of the above calculations, this paper selects the green economic efficiency (GF) value of each region as the explained variable.

(2) Explaining variables.

Environmental Regulation (ER). Regarding the measurement indicators of "environmental regulation", academic circles have different views, each with its own characteristics and deficiencies. For example, Rubashkina et al. (2015) [44], Song and Wang (2013) [45] use environmental pollution control investment to measure environmental regulations. Based on the availability and continuity of data, the representativeness of indicators, and previous research results, such as the methods used by Li (2020) [46], Zhang et al. (2020) [47] select industrial wastewater discharge compliance rate, industrial sulfur dioxide removal rate, The comprehensive utilization rate of industrial solid waste and the removal rate of industrial smoke (powder) are four individual indicators, and each individual indicator is normalized, and then the final environmental regulation level is calculated by the entropy method. However, due to the long time series of the data used in the study and a wide range of coverage areas, problems such as missing data or changes in the statistical caliber will inevitably occur. Among them, the average growth rate is used for problems such as abnormal or missing values in individual years and provinces. Complementary method, mean value interpolation method, homogeneous mean value interpolation method, multiple interpolation method, and the use of adjacent or similar areas of the same year data instead of the same year, other similar indicators instead of scientific methods for data correction and completion [48-49].

First, use extreme value processing to standardize various indicators, namely:

$$UE_{ij}^{s} = \frac{UE_{ij} - min(UE_j)}{max(UE_j) - min(UE_j)}$$

Where i refers to the province (i = 1, 2, ..., 30), j refers to 4 pollutants (j = 1, 2, 3, 4), UE_{ij} is the data of each indicator, max (UE_{ij}) and min (UE_{ij})) refers to the maximum and minimum values of various pollutants in each province each year. UE_{ij}^{s} refers to the value after standardization, and the value range is between [0,1]. Second, calculate the adjustment coefficient of each indicator, that is, the weight wij. The calculation method is:

$$w_{ij} = \frac{E_{ij}}{\sum E_{ij}} / \frac{Y_i}{\sum Y_i}$$

Among them, w_{ij} is the weight of pollutants, E_{ij} is the discharge of pollutants, $\sum E_{ij}$ is the total discharge of the j pollutant; Y_i is the industrial added value of province i, and $\sum Y_i$ is the total industrial added value. After calculating the pollutant weight w_{ij}, calculate the average value awij of the adjustment coefficient from 2008 to 2020.

Finally, calculate the strength of environmental regulations:

$$ER_i = \frac{1}{4}\sum_{j=1}^{4} aw_{ij} \times UE_{ij}^{s}$$

Economic development level (GDP). Per capita GDP is used to express the level of economic development. Areas with high levels of economic development usually have more funds and advanced technologies to improve the ecological environment, but often economic growth is accompanied by an increase in investment, which brings aggravation of environmental pollution. Therefore, the final effect of the level of economic development on the efficiency of the green economy is uncertain.

Foreign Direct Investment (FDI). Domestic and foreign scholars have shown that there are two views on the impact of foreign direct investment on the host country. One is the pollution halo hypothesis. The hypothesis believes that when the host country introduces FDI, it will also introduce more stringent environmental standards, better management systems, and more advanced cleaner production technologies in developed countries, all of which will play a positive role in the development of the host country. In the process of foreign investment, multinational companies will use high-level clean and environmentally friendly technologies for production. On the one hand, they will directly reduce energy consumption intensity and pollution levels. The host country uses the learned production technology to improve the original extensive production methods, reduce energy consumption intensity, and improve environmental quality. The second is the “pollution refuge” hypothesis. This hypothesis believes that due to the stronger environmental awareness and higher environmental standards in developed countries, under the conditions of an open economy, in order to reduce costs, multinational enterprise groups will relocate a large number of production departments to developing countries, and these production departments often They are all high-pollution and high-energy-consuming types, which makes developing countries passively become “pollution refuges” for developed countries. However, developing countries have not taken measures to avoid becoming “pollution refuges”. Instead, there are cases in which they actively lower environmental standards for the development of their own economies in order to attract foreign investment, which makes the investment in the host country flow to high-energy Consumption sector. During this process, the energy consumption of the host country gradually increased, the energy utilization efficiency gradually decreased, and the environmental quality gradually declined. This article chooses the actual use of FDI/GDP to express. The unit of FDI is ten thousand U.S. dollars, which is calculated by converting the annual RMB to U.S. dollar exchange rate into yuan.

Table 3. Descriptive statistics of variables.

Variable	Mean	Standard deviation	Minimum	Maximum	Observed value
GF	0.3229	0.1392	0.1673	0.7787	390
ER	0.4342	0.2983	0.0034	0.1672	390
GDP	0.9732	0.3462	0.2637	2.1822	390
FDI	0.0473	0.0372	0.0032	0.1627	390
CF	0.1102	0.1622	0.1192	0.2372	390
k	0.2532	0.0873	0.0057	0.1833	390
IC	0.3672	0.0563	0.1722	0.4738	390

Fiscal Decentralization (CF). Since the research in this paper is inter-period time series and inter-regional panel data, the fiscal autonomy of the province's fiscal budget revenue to the province's expenditure at the same level measures fiscal decentralization. Fiscal autonomy is high and funds are available to boost the economy, but because the promotion mechanism only focuses on economic growth and ignores environmental issues, the impact of fiscal decentralization on the efficiency of the green economy is uncertain.

Investment in fixed assets (K). This article uses the ratio of the amount of fixed asset investment in different provinces to the GDP of each region to express. As one of the "troikas" driving the economy, increasing investment in fixed assets to increase the rate of capital formation plays an important role in the economic structure, economic strength, and living standards of residents. However, investment activities are also accompanied by waste of resources and increased pollution. Therefore, the higher the investment rate, the lower the efficiency of the green economy will be.

Industrial structure (IC). This article expresses the proportion of the total value of the secondary industry in the total output value of the city. The secondary industry is industry, which is a heavily polluting industry, and its high proportion may cause serious environmental pollution problems, which in turn will have a certain impact on the efficiency of the regional green economy.

Based on the existing literature and considering the availability of data, the following Tobit model is constructed:

$$GF_{it} = \alpha_0 + \alpha_1 ER_{it} + \alpha_2 GDP_{it} + \alpha_3 FDI_{it} + \alpha_4 CF_{it} + \alpha_5 K_{it} + \alpha_6 IC_{it} + \mu_{it}$$

In the model, the year is represented as t, i represent different regions, and the green economy efficiency is represented as GF. The data is derived from the previous calculations. Table 3 is the descriptive statistics of each variable. The overall Standard deviation of the data is small and stable.

Data Sources

This paper selects the annual data of 30 provinces (or autonomous regions or municipalities directly under the Central Government) in China from 2008 to 2020 as the basic data. All data indicators come from "China Statistical Yearbook", "China Environment Yearbook", "China Environment Statistics Yearbook", "China Environment Statistics Yearbook", "China Energy Statistics Yearbook", "China City Statistics Yearbook", "China Science and Technology Statistics Yearbooks and statistical yearbooks of various provinces. However, due to issues such as the availability of data, the Tibet Autonomous Region, Taiwan, Hong Kong and Macau are not included in the scope of this study. In order to reflect the changes in the actual level, when dealing with foreign direct investment data, this article uses the exchange rate of USD/RMB in the current year to convert the amount in RMB, and in order to minimize the impact of price factors on the conclusions of the measurement analysis, Economic data is converted from comparable price indices by regional price indices over the years.

Regression Results and Analysis

In this paper, the regression results using the Tobit model are shown in Table 4.

(1) Environmental regulations

From a national perspective, the impact of environmental regulations on the efficiency of the green economy (-0.144) has a restraining effect, which may mean that the cost of amendments to environmental regulations is relatively high, and it is difficult to effectively improve the efficiency of the green economy. From the perspective of different regions, in the eastern region, at the 5% significance level, the coefficient of environmental regulation on the green economy efficiency of the eastern region is significantly positive (0.214), environmental regulations have a restraining effect on the efficiency of the green economy; environmental regulations have a promoting effect on the efficiency of the green economy in the eastern region. The reason is that the eastern

Table 4. Regression results.

Explanatory variables	National	Eastern	Central	Western
ER	-0.144** (-2.14)	0.214*** (3.19)	-0.129*** (-6.89)	-0.072*** (-5.23)
GDP	0.121*** (3.98)	0.077 (0.19)	0.152***(3.45)	0.123*** (3.91)
FDI	-0.018*** (-4.88)	-0.034* (-1.92)	-0.028***(-4.19)	0.010 (0.56)
CF	0.134* (1.71)	0.238** (2.29)	-0.128** (-2.24)	-0.134** (-2.12)
k	0.066*** (3.12)	0.144*** (3.01)	0.071*** (4.13)	-0.051 (-1.02)
IC	-0.082*** (-4.98)	0.128 (1.03)	0.076*** (5.33)	-0.045 (-0.92)
R^2	0.9674	0.9831	0.9564	0.9036
N	390	143	104	143

Note: ***, **, * indicate significance at the levels of 1%, 5%, and 10%, respectively. The statistical values of t-test are in parentheses.

region has a relatively developed technology level, a strong R&D capacity for clean energy technologies, and a high level of environmental awareness among people. Different from this, environmental regulations have restrained to the green economy efficiency in the central and western regions has increased. The possible reason is that 80% of the resource-based cities in my country are located in the central and western regions, basically forming an extensive type of high consumption and high pollution. The growth model, the resulting environmental pollution and energy consumption problems cannot yet use environmental regulation as a means to effectively force the transformation of the industrial structure. At the same time, the cost of environmental regulation is less than the economic benefit cost, which increases the pollution emissions of enterprises. It is not conducive to the improvement of green economy efficiency. To sum up, there are significant differences in government control and economic development levels in various regions, making environmental regulations have both restraining and promoting effects on the efficiency of green economy; in the process of industrial structure adjustment, the positive effect of output value growth and the negative effect of pollution emissions. It is difficult to balance the effects, resulting in inconsistent impacts of environmental regulations on the efficiency of the green economy.

(2) Industrial structure

The impact of the industrial structure on the efficiency of the green economy is significantly negative (-0.082), indicating that the higher the proportion of the secondary industry in the regional GDP, the less conducive to the improvement of the efficiency of the green economy. From a regional perspective, the industrial structure of the eastern region has no significant effect on the efficiency of the green economy, and the degree of impact is relatively weak. It has not passed the significance test, but the coefficient is positive, indicating that the impact of the industrial structure of the eastern region on the green economy efficiency has not had a significant negative effect, which further shows that the eastern region is superior to the central and western regions in terms of pollution treatment capacity. The impact of industrial structure on the efficiency of the green economy in the central region is significantly positive (0.076), which is conducive to the improvement of the efficiency of the green economy. The impact of industrial structure on the efficiency of the green economy in the western region has not passed the significance test. The main reason is that the western regional economy level of development is low, and the increase in the proportion of the secondary industry has not had a significant impact, but the elasticity coefficient is negative, indicating that there is a trend of negative impact.

From the perspective of the level of regional economic development, its impact on the efficiency of the national green economy is positive, which is conducive to the improvement of the efficiency of the green economy. From a regional perspective, the level of economic development has a significant positive impact on the efficiency of the green economy in the central and western regions, and an insignificant impact on the eastern region. This may be due to the implementation of the national and regional coordinated development strategy, which has promoted the central and western regions to a certain extent. The development of green economy efficiency in the western region, while the stable and gentle economic development in the eastern region, has relatively small fluctuations, making its impact less obvious.

From the perspective of regional fixed asset investment, its impact on the efficiency of the national green economy is significantly positive, which is conducive to the improvement of the efficiency of the green economy; from a regional analysis, the level of fixed assets in the eastern and central regions has a significant positive impact on the efficiency of the green economy. The impact on the efficiency of the green economy in the western region is not significant. This may be because the investment in fixed assets in the western region has increased energy consumption and aggravated negative effects such as environmental pollution, which is not conducive to the improvement of green economic efficiency.

From the perspective of foreign direct investment, whether at the national level or in the eastern and central regions, the level of foreign direct investment significantly affects the efficiency of the green economy and is negative. The consumption of energy and the destruction of the environment will inhibit the impact of green economy efficiency; due to the weak market development in the western region and the fragile ecological environment, foreign-funded enterprises invest less in the western region, resulting in insignificant green economy efficiency.

From the perspective of fiscal decentralization, it has a positive impact on the green economy efficiency at the national level but passes the test at the 10% significance level, indicating that fiscal decentralization has a positive effect on the green economy efficiency in general. The eastern region fiscal decentralization has a positive effect on the green economy efficiency at 5%. The above differences are significantly positive. The reason may be that in the eastern region, the government exerted its information advantages, local resources, factor inputs, and provided public goods and services, thereby urging the economy to transition to a green economy and reducing environmental pollution while improving the economy. The central and western fiscal decentralization has a significant negative effect on the efficiency of the green economy at 1%. The reason may be that the economy in the central and western regions is underdeveloped, and the local government is greatly pursuing temporary economic growth, causing repeated real estate construction and waste of resources, making it difficult to transform the green economy.

Conclusions

Based on the super-efficiency DEA model, this paper calculates the green economic efficiency of 30 provinces (autonomous regions and municipalities) in China from 2008 to 2020. On this basis, the Tobit model is used to study the impact of environmental regulations on green economic efficiency, and the following conclusions and enlightenments are obtained:

(1) From the perspective of spatial distribution, the average value of the national green economy efficiency from 2008 to 2020 is about 0.60. The green economy efficiency level in the eastern region is significantly higher than the national average, and the green economy efficiency index in the central region is second only to the eastern region. The green economy effciency indexes of the western region are all less than 1. From the perspective of time series changes, it can be roughly seen that during the period from 2008 to 2020, whether it is in the eastern region or the central and western regions, the efficiency of the green economy has been showing a slow upward trend. In general, the efficiency of China's green economy has continued to increase.

(2) The impact of environmental regulations on the efficiency of the national green economy has a restraining effect. From the perspective of different regions, in the eastern region, at the 5% significance level, the coefficient of environmental regulation on the green economic efficiency of the eastern region is significantly positive, and the coefficient of environmental regulation in the central and western regions on its green economic efficiency is significantly negative.The impact of regional environmental regulations on the efficiency of the green economy is not yet obvious. There are significant differences in the intensity of government control and the level of economic development in each region, making the impact of environmental regulations on the efficiency of the green economy both restraining and promoting.

(3) The impact of industrial structure on the efficiency of the national green economy is significantly negative, the industrial structure in the eastern region does not play a significant role in the efficiency of the green economy, and the impact of industrial structure on the efficiency of the green economy in the central region is significantly positive. The impact of regional green economic efficiency has not passed the significance test; the impact of regional economic development on the national green economic efficiency is positive, the impact on the green economic efficiency of the central and western regions is significantly positive, and the impact on the eastern region is not significant; fixed. The impact of asset investment on the efficiency of the national green economy is significantly positive, the level of fixed assets in the eastern and central regions has a significant positive impact on the efficiency of the green economy, and the impact on the efficiency of the green economy in the western region is not significant; foreign direct investment is either at the national level or at the national level. In the eastern and central regions, the level of foreign direct investment significantly affects the efficiency of the green economy and is negative; fiscal decentralization has a positive impact on the green economic efficiency of the country and the eastern region, and the central and western fiscal decentralization has a positive impact on the green economy efficiency. The % is significantly negative respectively.

Based on the above conclusions, this article provides suggestions for improving the efficiency of the green economy from the following aspects:

To give full play to the positive impact of environmental regulations on the efficiency of the green economy, it is also necessary to recognize the nature of the phases of economic development, and take advantage of the positive externalities brought about by regional economic advantages, to make full use of the advantages of local talents, technology and capital, to put people first and to innovate As a guide, actively promote the rationalization and upgrading of the industrial structure, and promote the improvement of green economic efficiency in all aspects.

Further expand opening to the outside world improve the quality of foreign capital utilization. Expanding opening to the outside world is conducive to introducing advanced foreign technology and experience into the country, improving the backward production techniques of some domestic industries, and further increasing green productivity. The traditional model of attracting foreign investment is mainly to bring in capital and solve the employment problem, but it also brings a series of problems. Many foreign companies only use Chinese cheap labor and huge market to earn high profits for them. All of the investments are processing procedures with low added value and low technology content, which also put a lot of pressure on the environment. At this stage, with the continuous development of Chinese economy, the advantages of population and other factor endowments are gradually disappearing, and the mode of attracting investment should also change accordingly. We must continuously improve the quality of using foreign capital, introduce some foreign advanced and environmentally friendly industries and processes, and promote technology. Progress and improve the efficiency of the green economy.

Implement industrial restructuring. The industrial structure focusing on high-polluting and high-energy-consuming industries is no longer suitable for current development needs. Reducing the proportion of high-polluting and high-energy-consuming enterprises and vigorously developing the service industry is the key to achieving industrial transformation and upgrading. The government should increase the research and development of environmental governance technology and clean energy, transform the factor endowment structure, increase the proportion of technology-intensive industries, increase the intensity of supply-side reforms, achieve a balance between environmental protection and economic development, and promote economic recovery.

It is necessary to fully understand the significant differences in the impact of environmental regulations on the efficiency of regional green economy. Regions should make rolling revisions based on the acceptable scope of enterprises, innovate a variety of environmental regulation methods, rely on the government's compulsion and market incentives, and fully tap the potential of environmental regulations to drive green economic efficiency.

Raise public awareness of environmental protection and establish a good network ecosystem. In the process of environmental governance, through environmental economic investment, ethical environmental civilization education, etc., strengthen the public's awareness of environmental protection and participation in governance to the entire society, let the public consciously participate in the process of environmental improvement activities, and promote public governance as an important channel for environmental governance. The government should proceduralize public participation, formulate and implements public policies, establishe a public network platform, and links with other functional departments to form a network solution chain to promote the expansion of the government's corporate citizen governance environmental ecosystem effect.

Conflict of Interest

The authors declare no conflict of interest.

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